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Strategies for Reducing Mosquito-Borne Disease Vulnerability in Equine Populations: A Kentucky Case Study

Sara Dalton
Western Kentucky University

STRATEGIES FOR REDUCING MOSQUITO-BORNE DISEASE VULNERABILITY IN EQUINE POPULATIONS: A KENTUCKY CASE STUDY

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Sara Elizabeth Dalton

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Date Recommended July 21, 2006

Research Committee Approval:

Katie Algeo 7/21/06

Dr. Katie Algeo, Director of Thesis

David J. Keeling 7/21/06

Dr. David Keeling

7/20/06

Dr. Jun Yan

Charles E. Anderson

Dr. Charles Anderson

Richard G. B

Dean, Graduate Studies and Research

23 July 2006

Date

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

STRATEGIES FOR REDUCING MOSQUITO-BORNE DISEASE VULNERABILITY IN EQUINE POPULATIONS: A KENTUCKY CASE STUDY

Sara Elizabeth Dalton Date: July 7, 2006 Pages 80

Directed by: Dr. Katie Algeo, Dr. David Keeling, Dr. Jun Yan, and Dr. Charles Anderson

Department of Geography and Geology Western Kentucky University

This research examined equine management practices that limit or contribute to the spread of West Nile virus and other mosquito-borne disease. I hypothesize that there is a relationship between equine management practices and outbreaks of mosquito-borne disease in horse populations. Improved and appropriate mosquito habitat management may limit the risk of mosquito-borne disease in humans and horses by helping to lower the mosquito populations. The study goals were to recognize equine management practices and mosquito prevention practices that foster outbreaks of mosquito-borne disease.

This study used a questionnaire for county level analysis of equine management practices and the relationship to mosquito-borne disease. This study is important because horses live in a natural setting among unmanaged elements, such as pastures with ponds, wooded areas, and riparian areas. However, horses themselves are highly managed. Equine management practices include pasture horses, who live exclusively outdoors, stabled horses who receive some turn-out time, and ultra-managed horses, such as race horses. Kentucky's economy is partially dependant on the horse industry, which is responsible for over 51,000 jobs and is a major part of the culture of Kentucky. Equine

diseases can significantly affect this section of the state's economy.

The study area consisted of three categories of noncontiguous counties, with each group containing three to four Kentucky counties. The three selected categories of study highlighted areas of West Nile virus incidence in equine populations. Surveys were distributed to horse owners and barn managers to collect data on differences in equine management practices and outbreaks of mosquito-borne disease. Two categories represented counties with large equine populations, and one category represented counties with low equine populations. Category I consists of the three counties that were selected based on high horse populations and high incidence of West Nile virus in 2002 -- Barren, Fleming, and Nelson counties. Category II consists of four counties with high equine populations and low incidence of West Nile virus in 2002 - Allen, Grant, Jessamine, and Meade counties. The third category looks at low equine populations and high incidence of West Nile virus in 2002 – Carlisle, Marion, Russell, and Todd counties. Areas with low equine populations and low incidence of West Nile virus were not considered for the study because those areas do not have either high horse populations or high incidence of West Nile virus and hence were not relevant for this particular research question about equine management practices.

A minimum of thirty surveys was collected for each category. Statistical analysis was used to determine relationships between incidences of disease, management practices, and knowledge of mosquito prevention. Each survey question was analyzed using the two-tailed version of the two-sample difference of proportion test.

West Nile virus is an important disease to study due to the potential economic loss to the horse industry but also because the disease has been responsible for sickness and death in human and animal populations. I studied horses because of the their mix of unmanaged and managed habitat.

This study did find a difference in equine management practices when it came to vaccination to prevent West Nile virus occurrences in horse populations. Horse people in categories with high horse populations had a higher use of a West Nile virus vaccine to prevent disease than people use in the low horse population category. While statistics from this study show that there is little or no difference in other equine management practices between the three categories, this research demonstrates that few horse owners and barn mangers limit mosquito habitat around their animals or are aware of IPM techniques. Vaccination lowers the chance that a horse will develop West Nile virus, but it is important that active equine management programs include limiting mosquito habitat to assist in prevention of mosquito-borne disease. Limiting mosquito-borne disease is an important preventive strategy that could protect the health of both horses and humans.

CHAPTER I

INTRODUCTION

The processes of global climate change and globalization are contributing factors to the quality of human health around the world. Globalization can profoundly contribute to the spread of numerous health problems among humans and animals because of the centers of interaction driven by transport innovations. Similarly, global climate change is a factor in mosquito range expansion and could encourage the spread of new insect-borne disease in northern temperate zones (WHO, 1996). On a global scale, human migration and the worldwide movement of goods facilitate the spread of disease by diffusing new diseases into previously unaffected areas. For example, Dutch elm disease, which originated in Asia, was brought to the United States when diseased elm logs were imported from Europe in the 1930's (Friesen, 1995).

History indicates that global diffusion of disease is not a new phenomenon. The exploration of new lands for economic purposes allowed for the mixing of microorganisms, insects, plants, animals, and humans that previously were biologically isolated and hence had little or no resistance to new diseases. Alfred Crosby (Crosby, 2001, p.1) succinctly describes humankind's impact on global diffusion by saying "Humans have in the very last tick of time reversed the ancient trend of geographical biodiversification." For example, the European conquest of the New World was significantly aided by the introduction of small pox, typhus, typhoid fever, and influenza that substantially weakened the indigenous people of the region. Carl Sauer's works on Native American population decline argue that epidemics introduced by the Spanish contributed to a "catastrophic and rapid" loss of indigenous life (Denevan, 1996, p.391).

Also of historical geographical significance is the exposure of Europeans to yellow fever in the Caribbean and South America. In fact, one of the factors contributing to the decision by Napoleon to sell the Mississippi Valley to the government of the United States in April 1803 was the French army's experience with yellow fever in Haiti (Peterson, 1995). Zoonotic diseases have also been a cause of death for humans throughout time. Examples include the Bubonic Plague, which is transmitted by rats and fleas, rabies transmitted through the infected saliva of warm-blooded animals, and zoonoses such as West Nile virus with avian-mosquito transmission (Kruse *et al.*, 2004).

The United States has experienced how the transcontinental movement of people, animals, and plant-life contribute to making the world more vulnerable to disease. A recent demonstration of this process was the 1999 introduction of West Nile virus. Since its initial detection in New York City, the disease has spread rapidly. According to

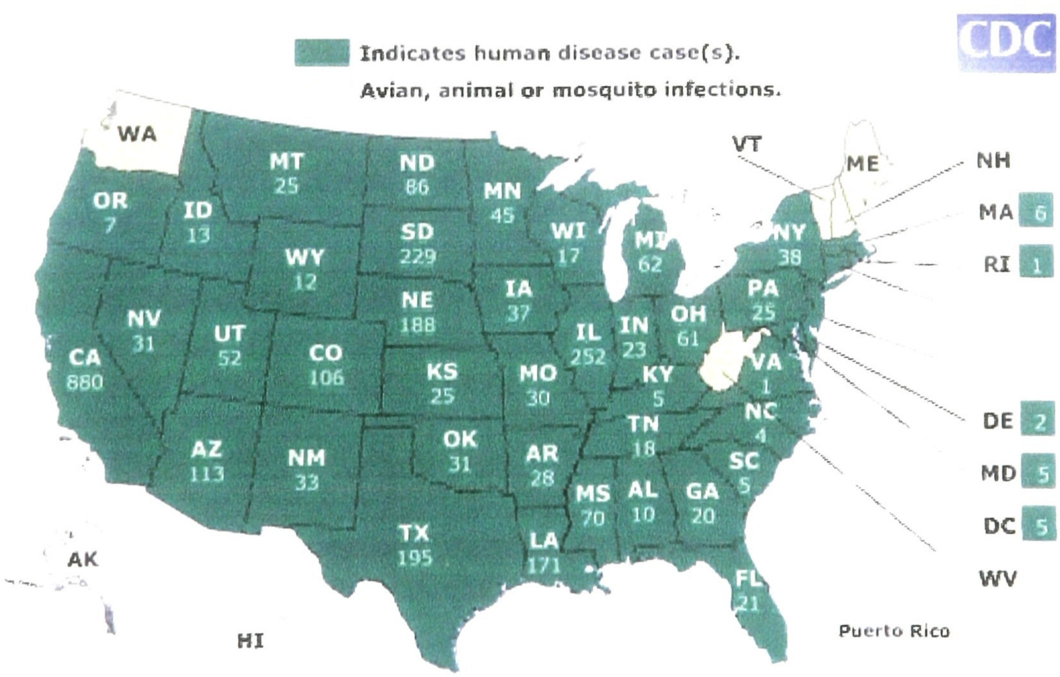


Figure 1: West Nile Virus Cases in the United States, 2005. Source: Center for Disease Control and Prevention, 2006.

the Center of Disease Control and Prevention (2006), West Nile Virus has now been detected in all states except Alaska and Hawaii. Figure 1 is a map of the United States showing the reported human and avian incidence of West Nile in 2005. The states in green have reported cases of human and avian West Nile virus. Tan states are those that have only reported avian cases.

Kentucky is known throughout the world for its elite horse industry, a substantial component of the state's economy and culture. This industry is threatened by the spread of diseases such as West Nile virus. Kentucky, and much of the United States, is located within a climate zone that is subject to mosquito infestation. There are over 2,500 mosquito species in the world, and 200 of these species live in the United States. Figure 2 maps the widespread distribution of one species of mosquito that carries West Nile virus found in the United States and Canada. In order to protect Kentucky's investment in

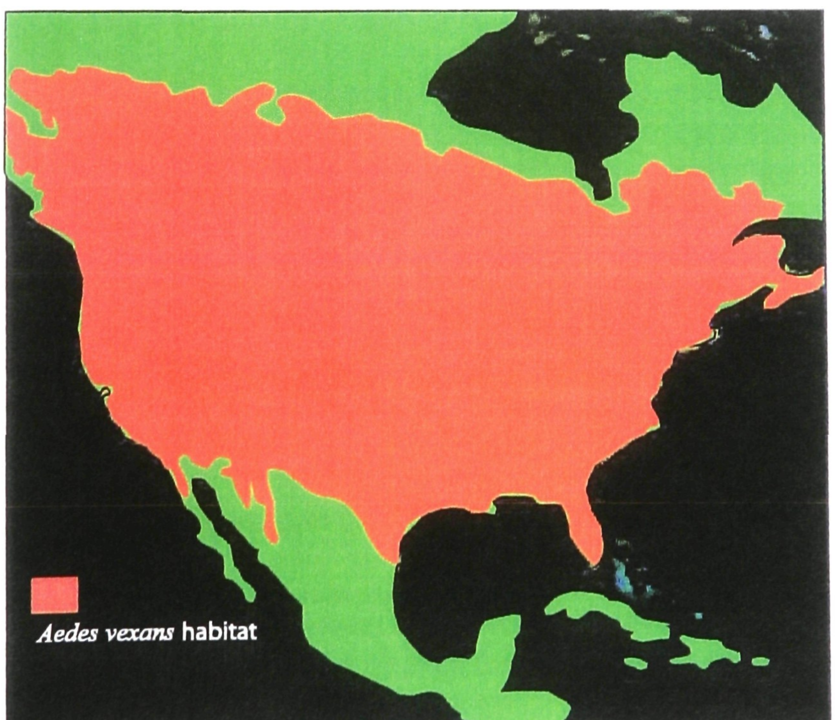


Figure 2: Distribution of *Aedes vexans* mosquitoes in the United States. Source: NASA/Goddard Space Flight Center Scientific Visualization Studio 2006.

the horse industry, management practices that prevent the spread of mosquito-borne disease should be encouraged within the state. Limiting the life cycle of the mosquito vector is an important preventative strategy that would help to protect humans and animals from mosquito-borne disease (McMicheal *et al.,* 1996). Though the equine industry has developed preventative vaccines that are effective against West Nile Virus, the vaccine has not been universally adopted within the horse community. Mutation of this virus or other mosquito-borne diseases also pose a threat to humans and equine health. Other mosquito-borne diseases that have caused problems in the recent past and continue to occur in the United States on a small scale include St. Louis encephalitis, Eastern Equine encephalitis, Western Equine encephalitis, Venezuelan Equine encephalitis, and LaCrosse encephalitis (CDC, 2006). Furthermore, drug resistant strains of diseases such as malaria and yellow fever and pesticide resistant mosquitoes continue to be a threat. Although the number of cases of West Nile Virus in Kentucky has declined from a peak of 513 equine cases (KDA, 2003) in 2002, other newly introduced mosquito-borne disease could pose a problem in the future.

Though West Nile Virus has been identified in birds, alligators, and mammals, the disease appears to be a health risk only in humans, horses, and birds. Horses are practical subjects for studying the distribution and impacts of West Nile virus because their geographic mobility is usually more spatially limited than that of birds or humans. They are also more intimately connected to the conditions of the local environment than are humans. Unlike birds, humans and horses do not spread West Nile virus. The virus does not get to levels in their bodies to make possible the transmission of the disease. Certain bird species, such as the American Crow, serve as amplifiers of the disease, potentially passing it on to other birds and mosquitoes (Rappole *et al.*, 2000).

The purpose of this research is to examine equine management practices within the state of Kentucky that might contribute to the geographic diffusion of West Nile Virus and other mosquito-borne diseases. My hypothesis is that there is a relationship between equine management practices and the number of cases of West Nile virus within horse populations in the state of Kentucky. Specifically, I hypothesize a difference in critical equine management practices between areas with high and low incidence of West Nile virus. The goals of this study are to identify the range of equine management practices in the state of Kentucky and examine methods of mosquito habitat management intended to reduce the risk of mosquito-borne disease in horses and humans by lowering the mosquito population.

Equine diseases, such as the mosquito-driven West Nile virus, can significantly affect the economy of Kentucky because the horse industry comprises such a large proportion of overall agricultural revenue. Equine management in Kentucky is pertinent to this study because horses live in a natural setting among unmanaged elements, such as pastures with ponds, wooded areas, and riparian areas. However, horses themselves can be highly managed. Moreover, the world-wide health risks associated with mosquito-borne diseases warrant further investigation of the methods by which the spread of these diseases can be better controlled among all animals, including humans, especially in consideration of the evolving world-scale processes of globalization and global climate change.

CHAPTER II

BACKGROUND

I. Origins of West Nile virus

A. Historical Indications

Modern understanding of West Nile virus dates to the early 20th century, but historical records suggest that this disease may in fact be much older. West Nile virus is a genus of the family Flaviviridae, a family of RNA viruses with a single-stranded positive-sense RNA genome (Petersen and Roehrig, 2001). Diseases such as yellow fever, dengue fever, and St. Louis encephalitis are members of this family. West Nile virus was initially isolated in 1937 from the blood of a woman living in Uganda. However, it was recently suggested by Marr and Calisher (2003) that Alexander the Great, who met with an early death at the age of 32, might have died a victim of West Nile virus in Babylon in 323 BCE. They cite Plutarch's record that, as Alexander entered the city of Babylon, flocks of birds were seen to be acting abnormally, and some birds collapsed and died at Alexander's feet. West Nile virus may have circulated throughout the Middle East for several centuries before the rapid global movement of commodities and people contributed to wider diffusion (Marr and Calisher, 2003). Before its introduction to the United States, cases of West Nile had been documented in Africa, Asia, and Europe (Deubel *et al.,* 2001). Abnormal avian deaths led to the initial discovery of West Nile virus in Brooklyn, New York, during late summer 1999. Since that time West Nile has migrated throughout the Western Hemisphere. Petersen and Roehrig (2001, 611) propose that "incursions of flaviruses (family *Flaviviridae*) into new areas are likely to continue through increasing global commerce and travel."

B. Transmission

West Nile virus is a zoonotic disease, a type of disease with a complex life cycle involving vertebrate hosts and a primary vector. In the case of West Nile virus, the vertebrate hosts are horses, humans, and birds, and the primary arthropod vector is the mosquito. Kruse *et al.* (2004, 2067) suggest that "most emerging infectious diseases in humans are zoonoses." Of all the identified pathogens acquired by human beings, 62% were found to have a zoonotic source. "Wild animals seem to be involved in the epidemiology of most zoonoses and serve as major reservoirs for transmission of zoonotic agents to domestic animals and humans" (Kruse *et al.*, 2004, 2067). West Nile virus is an arbovirus, a virus transmitted by arthropods, invertebrates with an exoskeleton, a segmented body, and jointed appendages articulated in pairs. The disease is transmitted through blood-feeding arthropods - in this case, mosquitoes primarily of the *Culex* and *Aedes* species. West Nile virus is one of a number of diseases that can be transmitted via mosquito to equines in the United States. Symptoms of West Nile virus in horses include fever, teeth grinding, blindness, inability to control muscle movements, failure to stand, paralysis of facial or limb muscles, and death. However, like humans, not every horse will exhibit signs of the disease (Ostlund *et al.*, 2001). Mosquitoes are the primary vectors, and birds are the key host (Salazar *et al.*, 2002). Some species of bird, such as the American Crow, *corvus brachyrhynchos*, act as a disease amplifier because a large amount of the disease circulates in their blood. The disease then passes to other animals through mosquito transmission (Rappole *et al.*, 2000). Migratory birds and ornithophilic mosquitoes, mosquitoes that primarily feed on birds as well as other animals, are believed to carry West Nile virus in the United States (Rappole *et al.*, 2000).

C. Other Arboviruses That Affect Equines and Humans in the United States

Arboviral encephalitides continue to cause problems in the United States with cases of this class of disease reported in horses and humans every year. Some arboviral encephalitides that affect both horses and humans in the United States include Eastern Equine Encephalitis, Venezuelan Equine Encephalitis, and Western Equine Encephalitis. Eastern Equine Encephalitis (EEE), thought to be the most deadly of the equine mosquito-borne diseases due to its high mortality rate, occurs primarily in the eastern United States (CDC, 2006). Thirty-five percent of humans that contract EEE die from the disease, and thirty-five percent who survive suffer acute neurological damage. Luckily, the disease is rare, with only 12 -17 cases of EEE occurring per year in the United States (Figure 6).

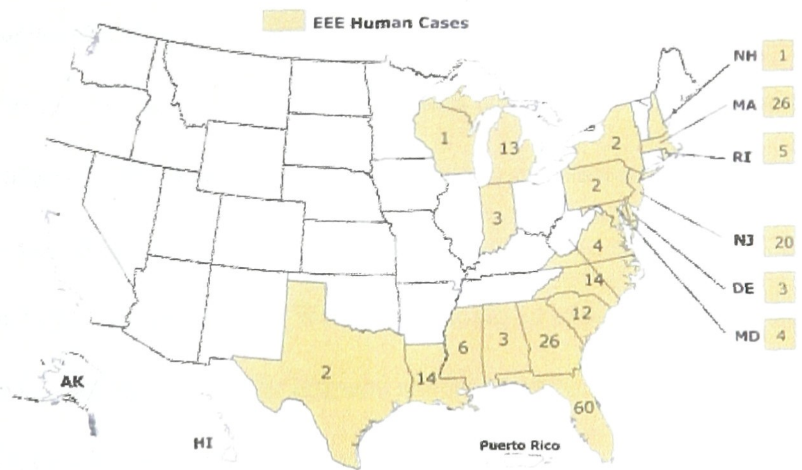


Figure 3: Human Eastern Equine Encephalitis in the United States between the years 1964-2004. Source: Center for Disease Control and Prevention, 2006

Unlike West Nile virus, horses are amplifiers of Venezuelan Equine Encephalitis (VEE), and studies have shown an eighty percent mortality rate in equids (CDC, 2006). Humans fare better, with less than a one percent mortality rate. Four percent of humans who contract the disease develop neurological symptoms. VEE outbreaks are rare in most of the United States, with most cases limited to Texas and Florida since the 1930's. The last severe outbreak in humans and horses occurred between the years 1969 – 1972 (EMedicine, 2004). An interesting side note is that VEE was fashioned into a biological weapon in the 1950's and 1960's by researchers in the United States and the former Soviet Union (CNS, 2006). Other mosquito-borne diseases that have been part of the United States defensive bioweapons research program include Western and Eastern equine encephalitis, yellow fever, dengue fever, Rift Valley fever, and Chikungunya disease (PBS, 2004). While the United States retains state-sponsored bioweapons programs, it was a signatory state at the Biological Weapons Convention of 1972 which "prohibits the development, production, stockpiling, and transfer of biological agents for use as weapons" (PBS, 2004). Given the past history and potential for these diseases as biological weapons, current concerns over national security create an additional incentive for understanding the management strategies employed to limit mosquito-borne disease.

Western Equine Encephalitis (WEE) is typically seen only in the central and western United States. Mortality rates for humans are three percent, with thirteen percent of those who contract the disease suffering from neurological effects. Horses that develop WEE have a twenty to fifty percent mortality rate, and the largest outbreak in humans and horses occurred in 1941 (Minnesota Department of Health, 2006). Komar *et al.* (2001) suggest the use of domestic animals as sentinels of West Nile to identify potential threats to humans and, in fact, horses are already used in some areas to detect Eastern Equine

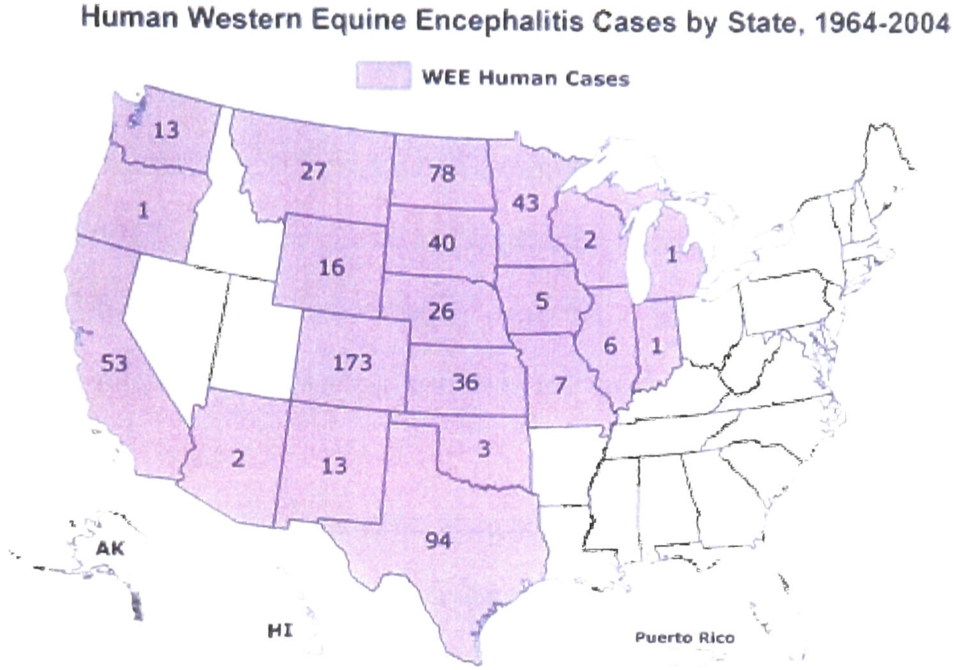


Figure 4: Human Western Equine Encephalitis in the United States between the years 1964-2004. Source: Center for Disease Control and Prevention, 2006.

Encephalitis and Western Equine Encephalitis. However, horses prove to be poor alert systems, as West Nile virus infections generally appear in horses in a region after human cases from that region have been detected (Trock *et al.*, 2001). While Eastern Equine Encephalitis, Venezuelan Equine Encephalitis, and Western Equine Encephalitis are worrisome, the diseases do not occur every year on a regular basis. The exact reason for periodic outbreaks of these diseases is not known. It is not yet known if West Nile virus will follow similar patterns of reduction and periodic resurgence, although a study conducted in southern France suggests that this might be the case (Murgue *et al.*, 2001).

II. Modern Diffusion

A. International

1. Health impacts

West Nile virus, first isolated in Africa, has traveled to the Middle East, Europe, Asia, and now, North America. While the disease was first isolated in 1937 from the blood of a woman living in Uganda, the disease was formally classified as a virus in Egypt in 1950. By 1957, the disease had reached the Middle East and scientists had discovered that West Nile virus caused inflammation of the spinal cord and brain. In the 1960's, West Nile was documented in humans and animals in Europe and East Asia. Before the disease made its way across North America, the largest known outbreak occurred in South Africa during 1974, when over 3,000 human cases were confirmed. The United States is not the only region that has experienced WNV outbreaks in recent years. Three extensive epidemics occurred in 1999 in Romania and Russia. These regions experience hot, dry summers, are on bird migration corridors, and are located close to significant amounts of water (Platonov *et al.,* 2001). In 2000, southern France had WNV return after a lapse of 35 years (Murgue *et al.*, 2001). A study of arboviruses in Hashimiah, Jordon, showed that humans living close to sewage treatment plants or effluent channels were more prone to WNV infection, presumably because of proximity to mosquito breeding habitat (Batieha *et al.*, 2000).

B. National

1. Health impacts

West Nile virus entered the United States through Queens, New York (Figure 6). The disease was most likely brought into the United States by infected birds or an infected mosquito. Unusual bird behavior and deaths in the area were the first signs of the disease (Rappole *et al.*, 2000). Since WNV's initial introduction to North America,

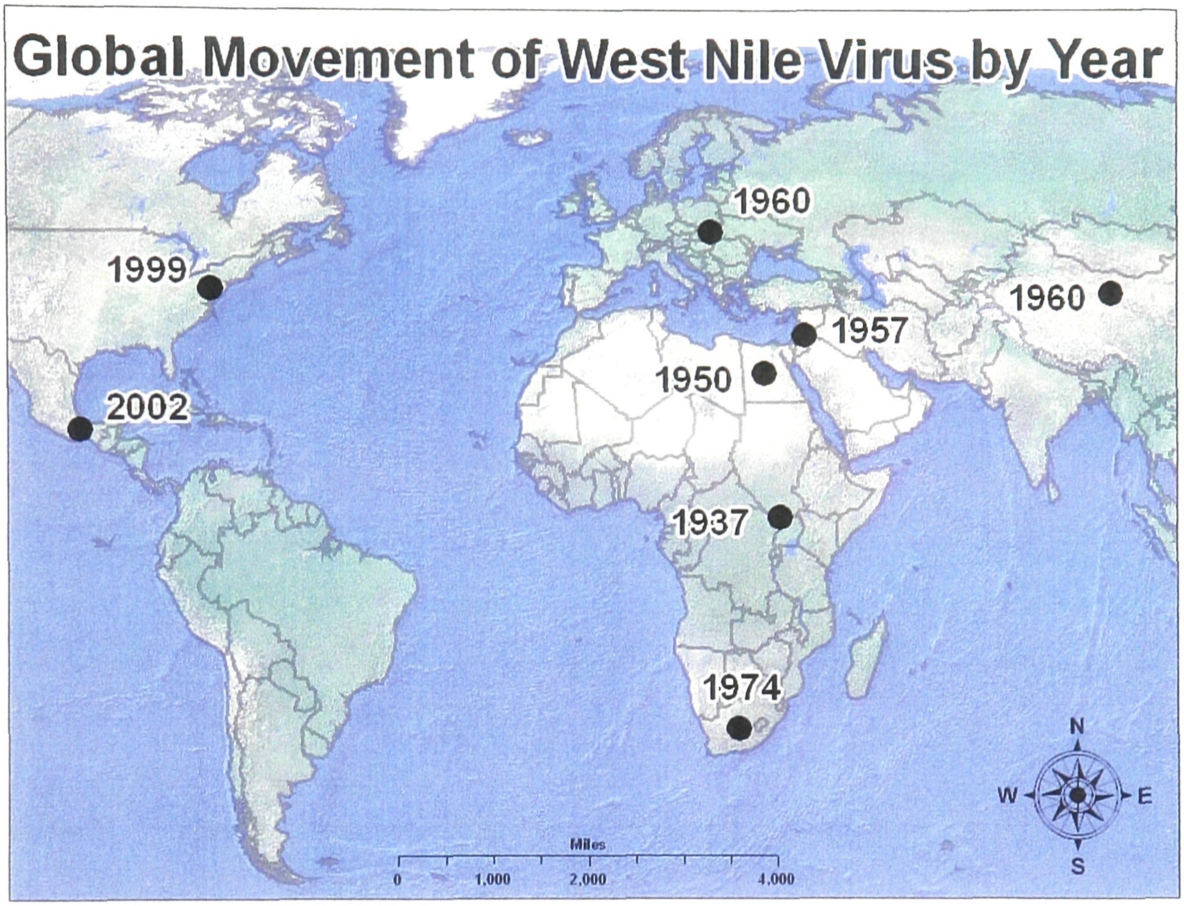


Figure 5: Progression of West Nile virus by year and region. Source: Rogol et al., 2002.

the virus has spread to the south and the west during periods of warm weather (Salazar *et al.*, 2002).

In the United States, more than 15,257 positive cases of equine West Nile virus have been reported since 1999, and over one third of these animals died (APHIS, 2003). As of June 2006, there have been a total of 19,710 human cases of West Nile virus, with 785 deaths (CDC, 2006). The precise number of West Nile virus cases is likely to remain unknown, as the disease does not always result in noticeable symptoms and not every horse and human that have the disease will be clinically tested by a medical professional. Both horses and humans are dead-end hosts of West Nile virus, meaning that the disease does not concentrate enough in their blood to infect a biting mosquito (Komar *et al.*, 2001).

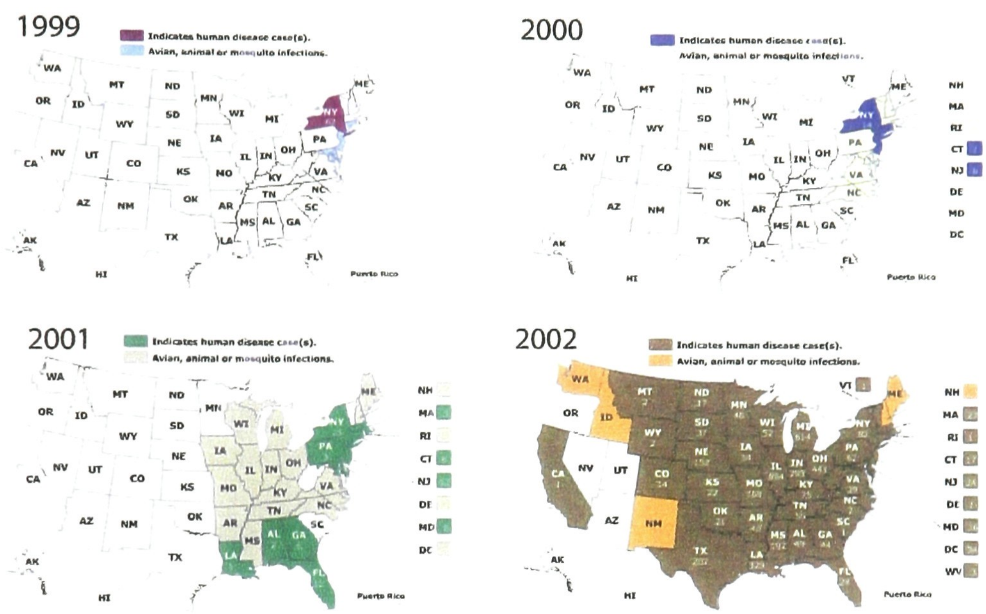


Figure 6: Human and Equine cases of West Nile virus, 1999 - 2002. Source: Center for Disease Control and Prevention, 2006.

2. Economic impacts

The agricultural industry contributes 1 percent to the economy of the United States with the equine industry contributing 31% to the total agricultural GDP. The horse industry's direct impact on the economy is $39 billion, and it creates $1.9 billion in taxes. According to the American Horse Council and Deloitte Consulting LLP (2005), the horse industry had a $102 billion impact on the United States economy in 2005 when considering the multiplier of spending by suppliers and employees. The horse industry operates in every region of the country and is incredibly diverse in its activities. Over 4.6 million Americans participate in the horse industry; this figure includes a range of individuals from horse breeders to those who decide to take a trail ride while on holiday.

This number also includes 1.4 million employed in the industry. According to the American Horse Council (2005), there were over 6.9 million horses in the United States in 1999. The population increased to 9.2 million in 2005, which is a 33 percent increase over six years. As the horse industry grows, the economic impact of horses grows as well, as do the impact and costs associated with equine-related diseases.

A study conducted jointly by Colorado State University and Nebraska State University (APHIS, 2003) evaluated the economic impact of West Nile virus on equine populations in Colorado and Nebraska. The study proposed that the cost to horse owners whose animals had contracted West Nile virus in the two states was greater that $1.25 million. The burden of preventing West Nile virus costs another $2.75 million for the horse owners. In this case, the cost of preventive measures outweighs, in a strict economic sense, losses to West Nile virus. These figures were determined in part by examining the average cost of an equid in the two states. According to the National Agricultural Statistics Service (APHIS, 2003), the average value for a horse in Colorado and Nebraska in 1998 was $1,420. The average value for a horse from Kentucky during the same year was $23, 214, yet the cost of vaccination is roughly equal. Of course, there are horses in Kentucky worth less than $1,000, many worth somewhat more, and a very few units over $1 million. In this scenario, it would not be economically rational to vaccinate all horses. Still, preventive treatment for West Nile virus in the average horse in Kentucky has the potential for a far greater economic savings than treatment for the average horse in Colorado or Nebraska.

C. Local

1. Health impacts

By May 2001, the state of Kentucky was gathering WNV data through the Center for Disease Control and Prevention and the University of Kentucky (Mahl and Billings, 2002). The first reported case in Kentucky equines occurred in Bourbon County in August of that year. Reported infection of horses in Kentucky peaked the week of September 1, 2002. That year, 513 positive cases in equines were reported from 78 Kentucky counties (KY Dept. of Agriculture, 2006) (Table 1). Since 2002, reported cases of West Nile virus have dropped drastically, perhaps through the combined effects of attention by the media, local mosquito management practices such as aerial spraying, and use of vaccinations.

Year	Number of Confirmed Cases in Equines
2001	8
2002	513
2003	102
2004	8
2005	8

Table 1: Cases of West Nile virus in equine populations, 2001-2005. Source: Kentucky Department of Agriculture, 2006

2. Economic impacts and globalization

The state of Kentucky is known throughout the globe for its elite horse-related industries, a substantial component of the state's economy. According to the Kentucky Department of Agriculture, horses are the foremost agricultural commodity in the state (Table 2). Kentucky horses also make up 81.8 percent of the value for all horses in the United States which makes Kentucky a significant contributor to the equine industry. The equine industry generated over $2.3 billion dollars for Kentucky in 2005 and employed more than 51,900 people in full-time positions (American Horse Council, 2005).

Therefore, mosquito-borne disease that affects horses has the potential to significantly impact agricultural productivity and jobs in the horse industry, affecting the state's economy.

	Value of receipts thousands $	Percent of state total farm receipts	Percent of US value
1. Horses & Mules	950,000	23.0	81.8
2. Broilers (meat fowl)	690,932	16.7	3.4
3. Cattle & Calves	620,650	15.0	1.3
4. Tobacco	421,694	10.2	27.8
5. Soybeans	372,216	9.0	2.0
All commodities	4,126,185		1.7

Table 2: The top five Agricultural commodities for the state of Kentucky in 2004. Source: United States Department of Agriculture, Economic Research Service 2006.

The horse industry, especially the thoroughbred racing industry, is very much part of the process of globalization. Globalization is the process by which social and business establishments function and interact on an international level (Keeling, 2004). An example of globalization in the equine industry is Darley Stud the breeding operation that is headed by Sheik Mohammed of the Saudi royal family. Bernardini the 2006 Preakness winner is owned by Darley Stud, which has breeding facilities in Ireland, the United Kingdom, France, the United States, Australia, and Japan. The United States operation is located in Lexington, Kentucky. Ashford Stud, also located in the Lexington area, is another multinational equine breeding facility. Ashford Stud's parent company, Coolmore, is based in Ireland and also has breeding facilities in Australia. According to Andrew Schweigardt (2006), Director of Industry Relations and Development at the Thoroughbred Owners and Breeders Association (TOBA), many foreign owned breeding facilities exist throughout the world. Thoroughbred owners can also be part of a syndicate where many owners invest in a particular racehorse. The owners split the costs and any prize money according to the percent of their initial investment. Another example of globalization applied to the thoroughbred racing industry is 'dual hemisphere breeding' (Schweigardt, 2006). Dual hemisphere breeding doubles the amount of stud fees that a stallion can generate during a breeding season. Thoroughbred racehorses must be conceived by live cover in order to be eligible for racing or registration (Stanback, 2002). Breeding season in mares runs from February to July in the northern hemisphere and from July thru December in the southern hemisphere. Shipping stallions for breeding purposes during the spring months in the northern hemisphere, and then again for the spring months during the southern hemisphere, maximizes the amount of money a stallion is able to generate throughout the year. The practice of shipping stallions around the world for dual hemisphere breeding has become a routine procedure in the globalized equine industry.

III. Future Implications and Prevention

Arboviral encephalitides are found around the world and can be prevented through individual defensive actions, such as applying insect repellent, and through reducing mosquito populations through insecticides and proper reduction of available mosquito habitat (CDC, 2005). According to the Center for Disease Control and Prevention (2006), the standard action taken against disease is a response to epidemics rather than prevention of disease. Actions that help to control the spread of mosquito-borne disease in horses include vaccination, the use of repellents, sanitizing drinking water containers, limiting and treating areas of stagnant water, and keeping animals indoors during peak mosquito-feeding periods. It is important to study whether these practices are being implemented by those in the community because active mosquito prevention can reduce the chance of mosquito-borne disease.

After it became clear that West Nile virus was a threat not only to human health but also to horses, pharmaceutical companies began looking for ways to prevent the disease. While a human preventative is not yet available, two vaccines are used in equine populations. The first West Nile vaccination, West Nile-Innovator, became available in August 2001 from Fort Dodge Animal Health. The second, Recombitek Equine West Nile vaccine, became available in early 2004 from Merial. The West Nile-Innovator, a killed, whole-virus vaccine, is 95 percent effective in preventing significant West Nile infection in horses (APHIS 2004). According to Merial, Recombitek, a modified live virus vaccine, also has a high rate of efficacy (Merial, 2006). Each vaccine is available from veterinarians and costs $18 (not including costs associated with administering the vaccine by a veterinarian). Both vaccinations, when initially given to adult horses, require two doses 3-6 weeks apart and a yearly booster. Foals that are given the vaccine for the first time require an additional third booster given 3-6 weeks after the second round of the vaccination and a yearly booster. The two vaccines are not interchangeable as each works differently. The vaccination process should be completed before mosquito season in any given year, with an additional booster given in late summer or fall in areas where the mosquito season exceeds 4 months (APHIS, 2003). Depending on the year, this season can include some or all of Kentucky. Although most horses are successfully vaccinated according to manufacture's instructions, no vaccine is 100 percent effective (APHIS, 2003). Horses that received the vaccination, however, are significantly less likely to need euthanasia or to die from West Nile infection (Salalzar *et al.,* 2002). Colorado State University claims that vaccination of horses against West Nile lessens the chance of the animal contracting the disease but notes that vaccination does not completely protect the animal under field conditions. Colorado State University urges horse owners not only to vaccinate according to the directions on the vaccine but to also use other approaches to prevent infection by mosquito.

Climate directly affects mosquito abundance, with temperature being the most important factor (McMichael *et al.,* 1996). As temperature increases, the metabolic development of the mosquito also increases. A faster metabolism results in earlier and more frequent blood meals for the female mosquito; eggs are also laid and hatched more quickly. As winters warm through global climate change, mosquito season comes earlier and leaves later (Patz and Olson, 2006). The amount of precipitation a region receives influences mosquito populations as well because the larvae and pupae stage are aquatic. Areas that experience frequent rainfall during warm months provide habitat for the early stages of the mosquito lifecycle (McMichael *et al.,* 1996). That said, Petersen and Roehrig (2001) caution that oversimplification of weather processes has not been accurate in predicting other mosquito-borne disease and should not be used to anticipate occurrences of West Nile.

Integrated Pest Management is also being used to combat insect-borne disease. Integrated Pest Management programs incorporate observation of the vector, reduction of habitat for the vector, administration of vector-control procedures, and education of the public. Mosquito habitat can be reduced by application of larvicides in open-water sources and making sure water does not have the chance to puddle or stagnate. Biologic controls incorporate the use of mosquito predators, such as bats, fish, dragonflies, amphibians, and reptiles. Applying entomopathic fungus to mosquito larvae will eventually kill the mosquito host through suffocation, but this process is slow and therefore is limited in its use. Many counties across the United States have implemented mosquito prevention and control programs; however, many of these programs are under funded and undermanned so that application of mosquito adulticide is the only prevention used in practice. While mosquito repellents are useful in preventing nuisance bites and may lower disease transmission, repellents "should not be relied upon to prevent disease transmission particularly where Lyme disease or encephalitis are endemic or malaria, yellow fever, or other vector-borne diseases are prevalent" (Rose, 2001, p. 21). The World Health Organization (WHO) does not condone the repeated use of pesticides as "long term application of pesticides may favor the emergence of resistant vector strains, while at the same time destroying predator populations that under normal circumstances would contribute to restricting the size of the vector populations" (McMichael *et al.*, 1996, p.91). Evaluation of mosquito-borne disease-prevention practices, including vaccination and IPM, need to be examined, as it is important that people are not only learning about these procedures but also implementing these techniques.

CHAPTER III

STUDY AREA

The first step in determining management practices that contribute to the spread of West Nile Virus was to narrow the study area to fit the scope of this project. As I examined the West Nile maps available from the Center for Disease Control and Prevention, I observed that counties varied greatly in their incidence of West Nile virus. Therefore, a subset of Kentucky counties was selected to illustrate extremes, both high and low, in incidence of West Nile virus. The year 2002 saw the highest rate of West Nile virus infection in horses in Kentucky. Therefore, data from that year were used to select

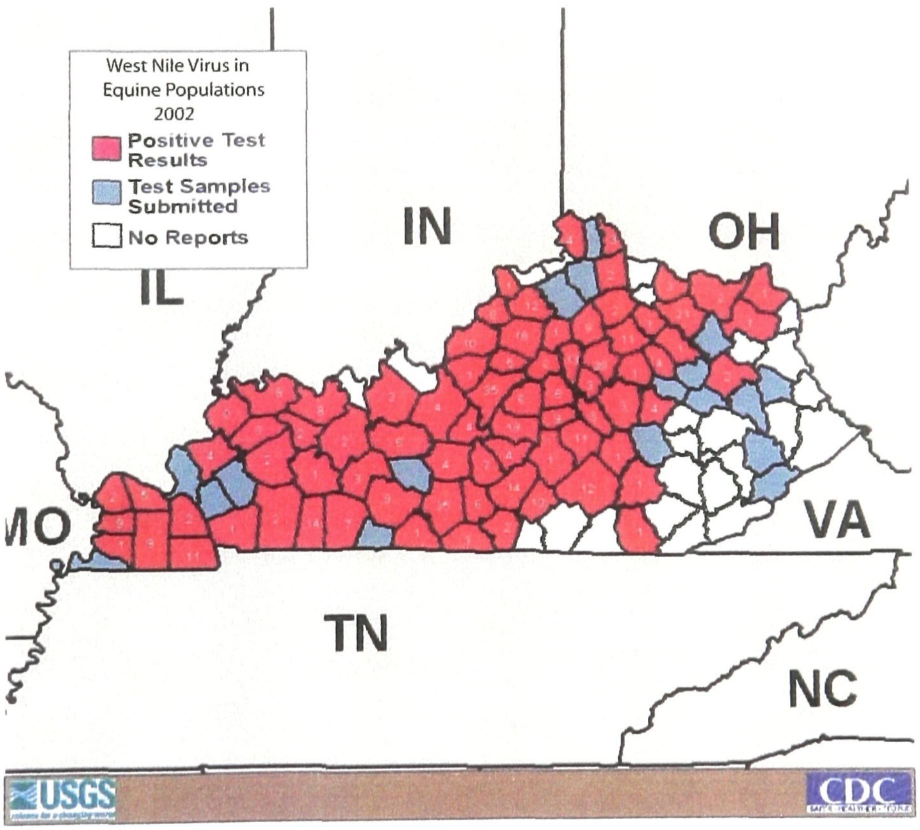


Figure 7: Example of an interactive map produced by the CDC and USGS showing West Nile virus in equine populations by Kentucky county, 2002. Source: Center for Disease Control and Prevention and U.S. Geological Survey, 2006.

the study area counties. West Nile Virus data for that year were collected from the Kentucky Department of Agriculture's (KDA)/ Division of Animal Health. The KDA (2002) website displayed West Nile virus occurrences by county and separated the occurrences for humans, horses, birds, and mosquito pools in those counties (Figure 7). For the purposes of this study, West Nile Virus cases in horses for the peak year 2002 were analyzed. Kentucky state agricultural census data for equine populations throughout the state were collected from the US Department of Agriculture (2003) website. Kentucky state agricultural census data were collected from the US Department of Agriculture (USDA) website for 2002 in order to facilitate the examination of equine population by county.

Horse populations per Kentucky county were entered into a Geographic Information System (GIS) attribute table using ESRI's ArcInfo™ 8.3 software. Information added to this database included 2002 West Nile virus in equine populations by county from the Kentucky Division of Animal Health. Maps showing equine populations and equine West Nile virus occurrences were created from these data (Figures 8 & 9). This data was used to determine the horse density by county, allowing me to account for the fact that counties have different sizes. Raw horse populations likely reflect, in part, the size of a county (i.e., large horse populations in large counties and small horse populations in small counties). The density allows identification of real patterns of equine population distribution. To determine horse density in Kentucky counties, horse populations per county were divided by area the of the county:

$$\text{Density} = \text{Horse Population/Area}$$

New fields were added to the attribute table for data I collected and for derived variables.

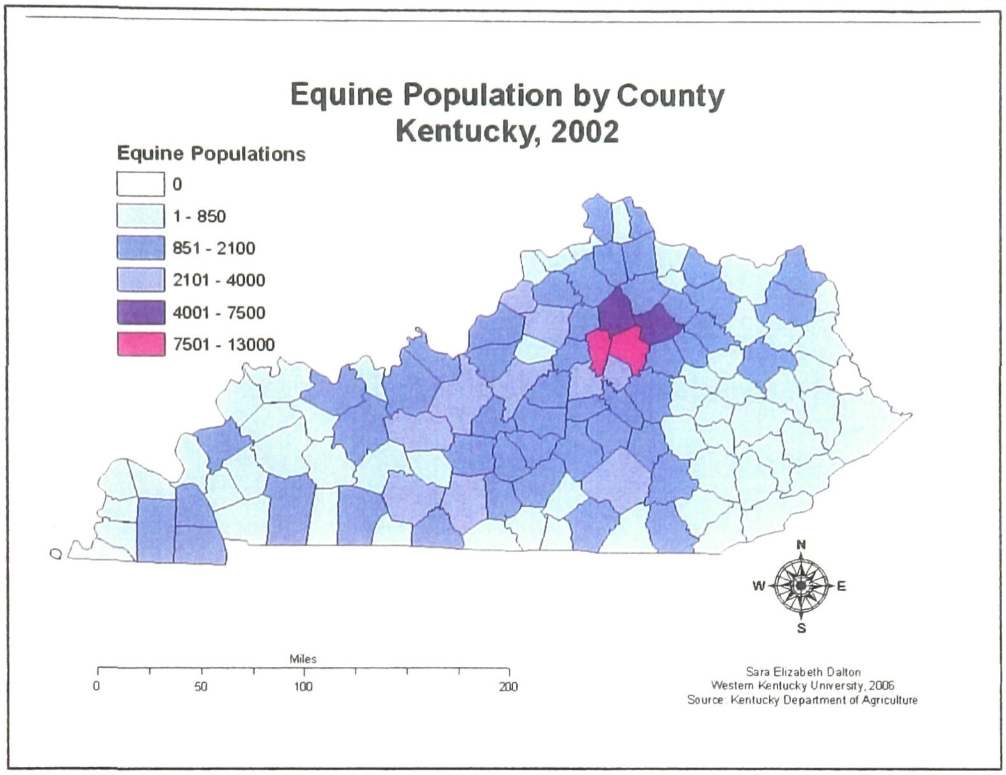


Figure 8: Kentucky Equine populations by county, 2002. Source: Kentucky Department of Agriculture

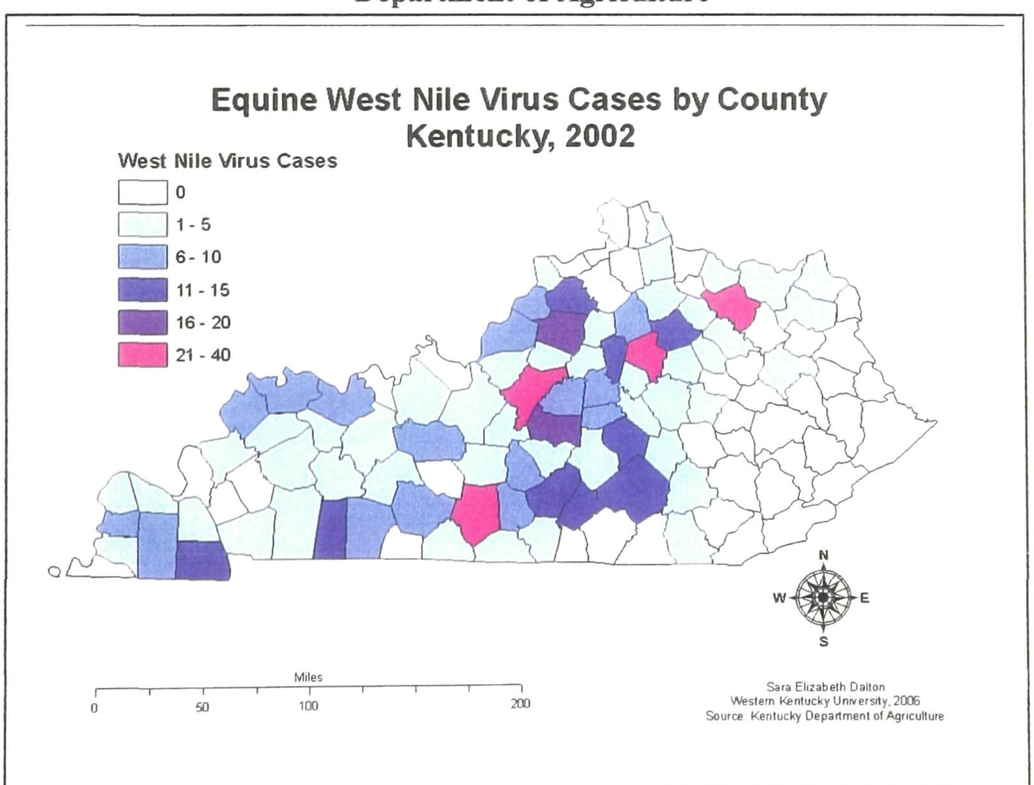


Figure 9: West Nile virus in Kentucky Equine populations by county, 2002. Source: Kentucky Department of Agriculture

The fields in this table already contained Kentucky census information and county areas. The new fields were created to enter data concerning West Nile virus (Appendix 1) and Kentucky equine populations (Appendix 2). In addition, a new field was created for the derived variable, density. Equine populations per square mile were calculated by dividing equine population by area. Figure 10 shows the resulting distribution of horses densities. Next, the West Nile index was produced. The West Nile index normalizes West Nile virus cases by equine density.

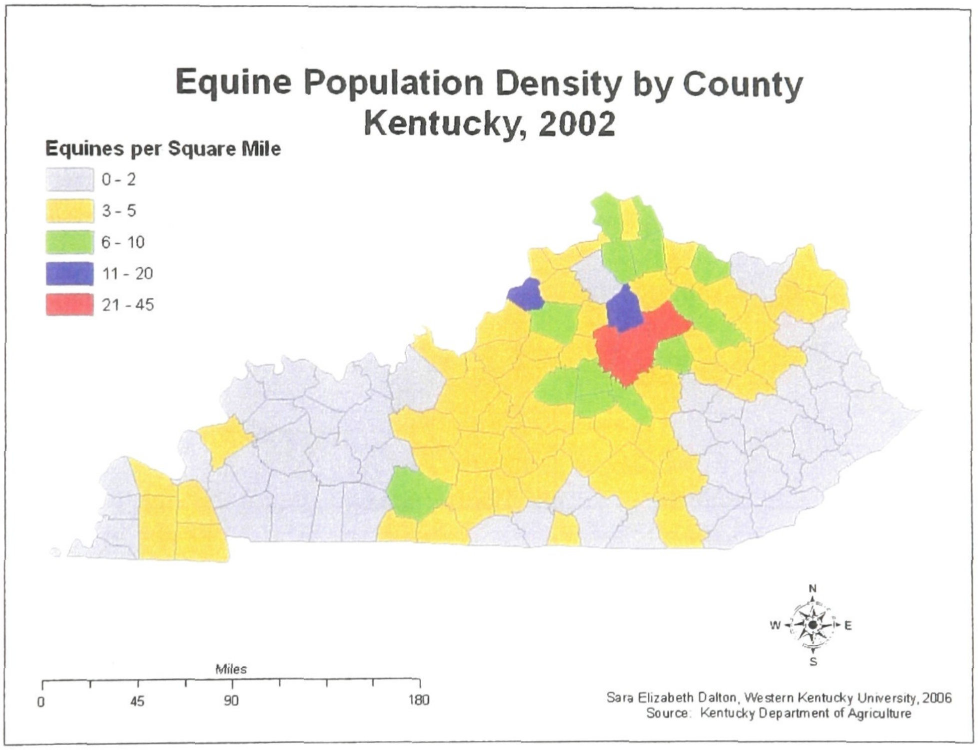


Figure 10: Density of Kentucky Equine populations by county, 2002. Source: Kentucky Department of Agriculture.

This index is used rather than the percent of horses infected, because the latter figure will be large either when one area has a large number of infected horses or a small number of infected in a small horse population. To find the West Nile virus index for each county, the equine West Nile virus cases per county was divided by equine density using ArcGIS. The following formula was used to find the West Nile index:

West Nile virus Index = Equine WNV cases per county / Equine Density.

The mean county horse population in 2002 was 1,243. The mean value for the West Nile virus index for 2002 is 0.003262. Using both the mean value of horse populations and the mean value for the West Nile index, the following table was created to find Kentucky counties with high horse populations and high incidence of West Nile virus, high horse populations and low incidence of West Nile virus, and low horse populations and high incidence of West Nile virus. Counties above the mean value (1,243) for horse population were considered counties with high horse populations. Counties below the mean value of 1,243 were considered counties with low horse populations. Counties above the mean (0.003262) for West Nile virus index were considered counties with high incidence West Nile virus and counties below 0.003262 were considered counties with low incidence of West Nile virus.

From table 3, the equine density map, and the West Nile index, three categories were created highlighting extremes in equine population and incidence of West Nile virus. Further analysis narrowed the counties selected from categories I, II, and III to be included in the study area (Figure 12). Category I county results show the highest incidence of disease and the highest horse populations. The three counties with the highest horse populations and highest incidence of disease were Barren, Fleming, and Nelson counties. These counties were the focus for the High Horse/High West Nile Category I. Although my initial intent was to survey only horse owners and barn

	High Horse Populations >1,243 (mean value of horse populations)	Low Horse Populations <=1,243 (mean value of horse populations)
High rates of West Nile virus in horses for the year 2002 >0.003262 (mean value of disease rates)	**Category I**	**Category III**
Low rates of West Nile virus in horses for the year 2002 <=0.003262 (mean value of disease rates)	**Category II**	**Category IV** (This category was removed because of the lack of equines and incidence of WNV)

Table 3: Categories created using the mean value of West Nile virus Index and the mean value of horse populations. Source: Based on survey data.

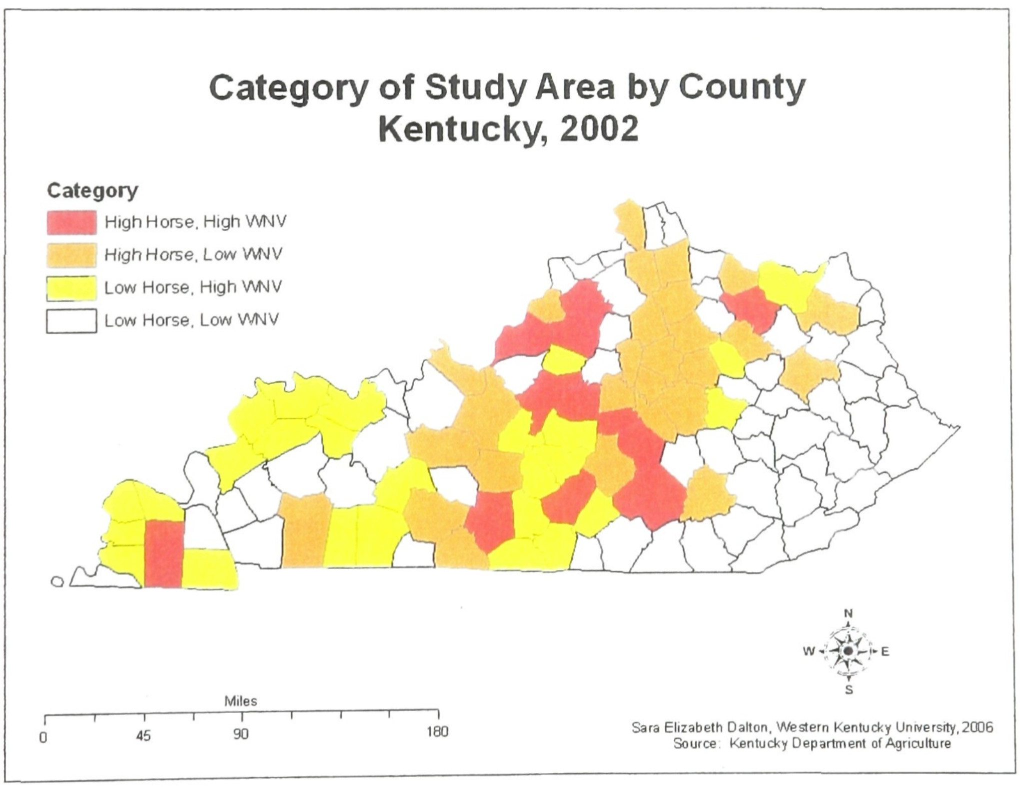


Figure 11: Counties categorized by horse population and West Nile virus index. Source: Kentucky Department of Agriculture.

managers from these three counties, when analyzing Category I areas, I ended up including Pulaski County to create an adequate sample size. Category II counties were selected based on low incidence of disease but significant horse populations. Allen, Jessamine, Grant, and Meade counties were selected to represent the High Horse/Low West Nile category. As with Category I, surveys from other counties were used to create an adequate sample size. The additional counties include Woodford, Scott, Laurel, Mercer, Christian, Warren, Harrison, Payette, Clark, Bourbon, and Madison. Category III included counties with horse populations below the mean value but with a significant incidence of West Nile virus. Marion, Russell, Todd, and Carlisle counties were the focus for the Low Horse/High West Nile category. As with Category I and II, surveys from other Category III counties were used. These include Larue, Metcalf, Union, and McLean.

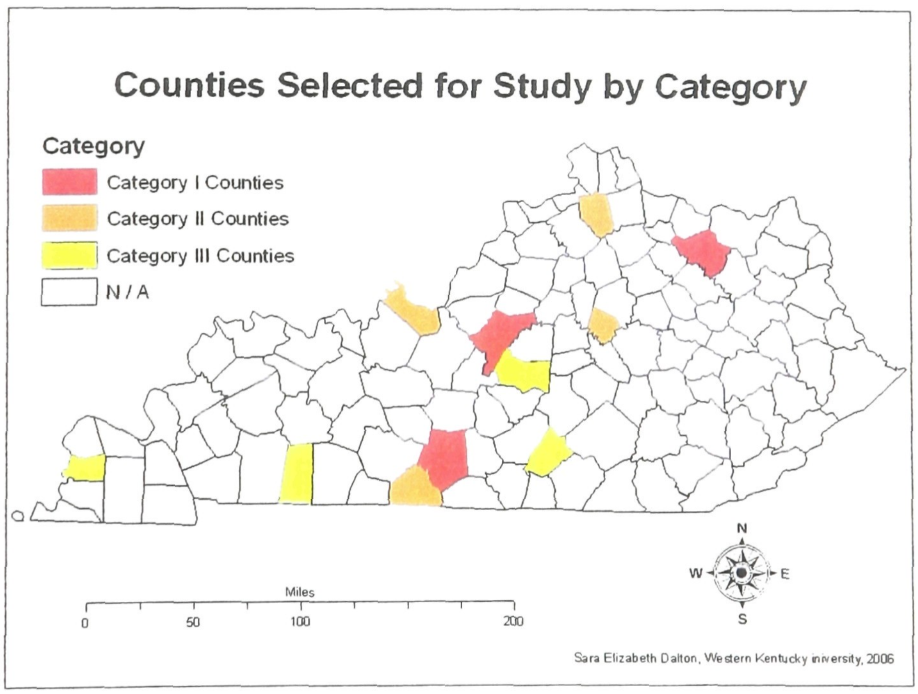


Figure 12: Study Area. Source: Kentucky Department of Agriculture.

Counties in a category are analyzed as a group because they represent areas with similar characteristics in terms of horse population and incidence of West Nile virus. In each category, I sought 30+ surveys with resident horse owners and barn mangers to determine equine management practices and to look for correlations between management and disease. I hypothesized that there would be a difference in equine management practices and IPM practices between each category. If there is a difference in practices between the categories, then perhaps new techniques could be used to reduce mosquito-borne disease exposure.

CHAPTER IV

DATA

Identifying relationships between cases of disease and geography have been used since Dr. John Snow mapped an outbreak of cholera in 1849 London, England. Since that time, geographical information has been used to control and prevent disease all over the world (Haggett,1994). West Nile virus information has been collected, and aspects of the disease, such as following the spread of West Nile and avian migratory patterns in North, Central, and South America, have been tracked by numerous researchers (Rappole *et al.,* 2000). The US government is also using technology to determine the parameters of West Nile and other mosquito-borne disease. The Center for Disease Control and Prevention (2006) has interactive maps depicting the spread of West Nile virus, and NASA (2002) has mapped four different mosquito habitats in the United States as part of its Earth Observing System (EOS) program (figure 2 is based on one of these maps). This program will eventually provide health organizations with satellite data depicting land surface temperature changes and other environmental indicators relevant to mosquito-borne disease such as vegetation and point data of West Nile cases.

In order to look at the differences between equine management practices in Kentucky, I administered questionnaires to horse owners and barn managers over a period of 20 months from August 2004 to March 2006. A similar study (Salazar et al., 2002) was conducted by the Nebraska Department of Agriculture in Nebraska and Colorado in 2002, although that study focused on the progression and outcome of horses that had been diagnosed with the disease. Interviewers worked with local veterinarians and Colorado State University, conducting interviews with horse owners whose animals had contracted the disease. The study was not concerned with methods of mosquito prevention in the locations around the horse's habitat, one focus of my study (Salazar *et al.*, 2002). I distributed my surveys to horse owners and barn managers via phone interviews, personal interviews at a variety of horse events, mail distribution to large animal veterinarians, and via volunteers from students in my class at Western Kentucky University. Personal interviews included talking with personnel at two equine breeding facilities and at the Kentucky Horse Park. These interviews differed from the surveys in that the interview process was longer, up to three hours, allowing for an in-depth discussion about concerns associated with West Nile virus, mosquito-prevention practices, and equine management techniques. At each facility, I was given a private tour of the horse facilities thereby allowing me to see first hand the equine management and IPM techniques used at each location.

Is there a difference in management practices between horse owners in Categories I, II, and III? Do horse owners and managers effectively protect their animals against mosquito-borne diseases? Do owners and managers limit sources of mosquito breeding habitat to help prevent mosquito-borne disease? To answer these questions, I designed a survey in order to elicit the level of concern over West Nile virus and to determine common equine management habits in areas with West Nile virus. Each subject was asked to read and sign a confidentiality agreement before the survey was administered (Appendix III). The survey took about five minutes to complete and was given one time to each individual willing to participate. Three of the surveys were conducted over the phone; however, the rest of the surveys were self administered, with each person surveyed filling out the survey individually. The survey questions were designed to determine the equine management practices that horse owners or barn managers use to prevent West Nile virus around their animals. First, respondents specified if they are a horse owner or barn manager and in which county they kept their animals. The survey asked for the number and breed of horses, as well as in what equine activities the respondents participate. These questions were designed to get background data on the respondents and find out if their county was in one of the categories of study. The next section of the survey was intended to find out if respondents were concerned about West Nile virus and if they had knowledge of Integrated Pest Management techniques. The following section asked the respondents if they were aware of the locations mosquito's used to breed and the duration of the mosquitoes life cycle. The fourth section asked the respondents where they observed for mosquitoes and the fifth section looked at the respondents' use of pesticides around their horses. The final section established West Nile virus vaccination practices and asked if any of the respondents' animals had an incidence of West Nile virus.

Initially, county extension personnel in the target counties were contacted to locate horse-people and equine activities in their area. I administered phone surveys to horse owners whose names were provided by the county extension agents. These interviews were seldom successful because horse owners were not often available during the daytime hours. I conducted three successful phone interviews.

Next, I collected surveys at county horse shows and other area equine activities. To conduct the survey, I randomly asked passers-by if they were horse owners or barn managers from Kentucky and if they would be willing to fill out the questionnaire. At a tack swap I attended, I reserved and set up a booth for surveys. I also approached horse people who were tending to their animals at trailers or barn stalls. Events I attended included a Western-style horse show in Barren County, a barrel racing show in Todd County, a tack swap in Jessamine County, a paint show in Woodford County, and several large horse shows at the Kentucky Horse Park. Of the 77 surveys I was able to collect by going to equine activities, only 14 survey respondents were from target counties.

As I encountered difficulty in getting the target number of surveys from some of my counties, I adopted a new strategy that attempted to enlist community insiders in the distribution of the survey. I mailed surveys to large-animal and equine veterinarians to be distributed to patients who are equine owners in the ten counties of focus. I located these veterinarians through the Yellow Pages for each county and called the veterinarian to inquire if he or she would be willing to participate by distributing the surveys to horse owners that visit their practice. The surveys were sent to seven willing veterinarians in September 2005. The packets included twelve surveys, each with a release form and a return-postage-paid envelope. Surveys were mailed back by December 2005. Ten surveys were collected in this manner.

Additionally, students living in the study counties enrolled in the interviewer's Spring 2006 World Regional Geography class at Western Kentucky University assisted in locating and collecting survey data from horse owners in their counties. I recruited students by asking if they were from one of the counties in the study area and if they knew horse owners or barn managers from that county. Five surveys were handed out to each student willing to participate the first week of spring session and were handed back by March 1st, 2006. Seven surveys were collected in this way. Once I used the "extra" surveys collected for each category, I had 20 surveys for Category I, high horse populations and high incidence of West Nile virus, 41 surveys for Categroy II, high horse populations and low incidence of West Nile virus, and 17 surveys for Category III, low horse populations and high incidence of West Nile virus.

I conducted personal interviews by going to equine facilities and calling veterinarians in the study areas. These interviews included personnel from two different breeding facilities, personnel from the Kentucky Horse Park and with two veterinarians. The first interview was conducted with the on-site veterinarian at a Woodford County thoroughbred breeding facility. While Woodford County was not one of the target counties, it is located in the High Horse/Low West Nile virus category (Category II). The second interview was conducted with the owner and barn manager at a Saddlebred breeding facility in Allen County, again located in Category II. Another personal interview was conducted with senior equine personnel at the Kentucky Horse Park in Fayette County, also located in Category II. Interviewing personnel from three facilities in the same category gave me the chance to compare three different management regimes in areas that had a low incidence of West Nile virus, although the counties had high horse populations. The interviews were conducted to examine the differences in breeding facilities and equine establishments. I was able to examine each facility's equine management and mosquito prevention practices. Conversations were initiated by asking about concerns associated with West Nile virus. However, many equine subjects were discussed, such as training, foal and mare management, and turnout time. During one of the interviews, I was even introduced to six draft show mules and got a tour of antique farm equipment.

The final two interviews were conducted over the telephone. The first of these was a conversation with a veterinarian working on animals in Fleming County. Fleming County is located in Category I because it has a high horse population and high incidence of West Nile virus. This interview gave me the chance to review the type of equine management practices a veterinarian would see while treating their patients. The second interview was a conversation with the Assistant State Veterinarian at the Kentucky Department of Agriculture. This interview allowed me to discern some of the issues the State had concerning West Nile virus.

CHAPTER V

METHODOLOGY AND SURVEY STATISTICS

Statistical analysis was used to determine relationships between incidences of disease, management practices, and knowledge of mosquito prevention. As the surveys were collected, data were entered into an Excel spreadsheet. The county of the respondent (question 4) and the category of the county (I, II, III) where the horses were kept were entered into Excel as text. Questions were then broken down so that each response could have a binary yes/no (1 = yes, 0 = no) answer. One exception, in addition to question 4, was question 12 (List all areas you believe to be mosquito-breeding habitat). Questions that were unanswered by a respondent were left blank. When all surveys were collected, the spreadsheet was split into three separate spreadsheets containing Category I, II, or III data. The totals for each answer in the categories were summarized.

I compared survey results for the sets of target counties with high horse populations and high incidence of West Nile virus, counties with high horse populations and low incidence of West Nile virus, and counties with low horse populations and high incidence of West Nile virus. For questions that could be answered with a yes/no statement, a qualitative two-sample difference of proportions test was used to compare the target sets by pairs. This test looks for significant differences in distribution across the categories between independent, random samples with two or more categories (McGrew and Monroe, 2002). Because I entered the data into an Excel spreadsheet using dichotomous data, this test was appropriate. The two-tailed test was suitable because of the nature of the alternative hypothesis. Both the Z-value and p-value statistics were used to see if a difference between categories exists. The Z-value is the test statistic calculated from a given set of survey responses.

$$Z_p = \frac{p_1 - p_2}{\sigma_{p_1 - p_2}}$$

Based on the normal curve, the p-value is the probability that the proportion of respondents answering "yes" in the two categories (county sets) is the same, i.e., that there is no statistical difference in responses. The p-value of 0.05 was used because it is a commonly accepted critical value in hypothesis testing. A p-value of less than 0.05 would show that a "difference" between categories very likely exists and the null hypothesis of "no difference" should be rejected.

CHAPTER VI

RESULTS

A total of eighty-eight surveys from twenty-seven different Kentucky counties were collected. Seventy-eight surveys were from the target counties. Horse owners accounted for 96 percent of all surveyed. The remaining 3 percent managed horses for someone else. Of those that participated in the survey, 43 percent derived income within the horse industry. The most popular breed of horse by those surveyed was the Quarter Horse (Figure 13). At least 62 percent of those surveyed owned one. The Paint, Tennessee Walking Horse, and the Thoroughbred, in that order, followed the Quarter Horse in popularity. Unfortunately, due to horse owners and barn managers having horses of several different breeds, it is impossible to accurately determine from this survey if there is a difference in management practices between breeds of horse. Trail riding

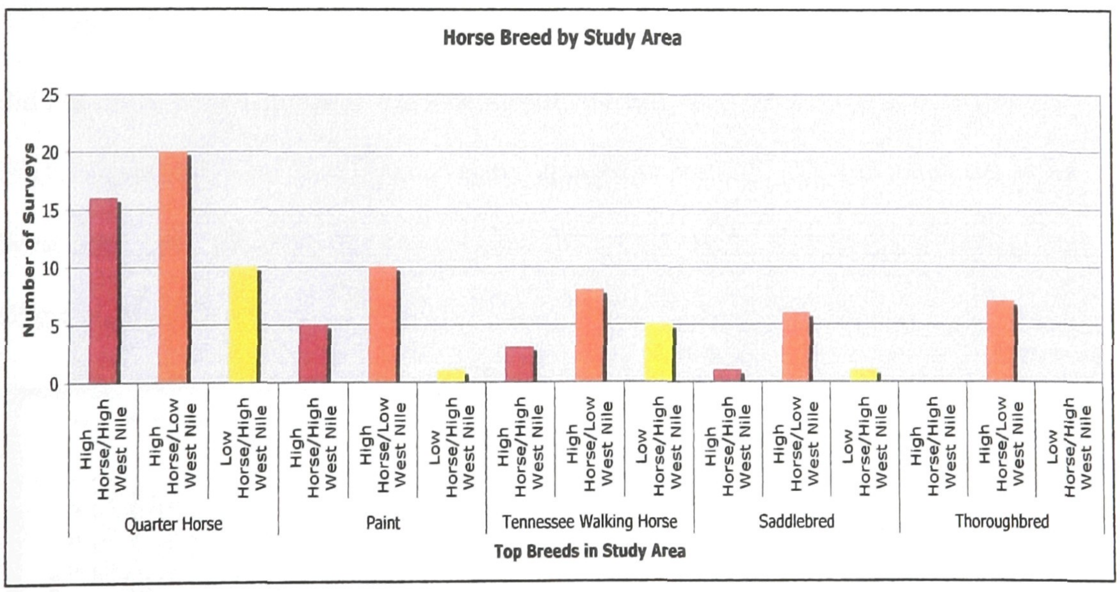


Figure 13: Most popular breeds of horse. Source: Survey data.

was the most common activity shared by horse owners, accounting for 57% of the total surveyed. Western Pleasure, Barrel Racing, and Horsemanship-all hobbies dominated by

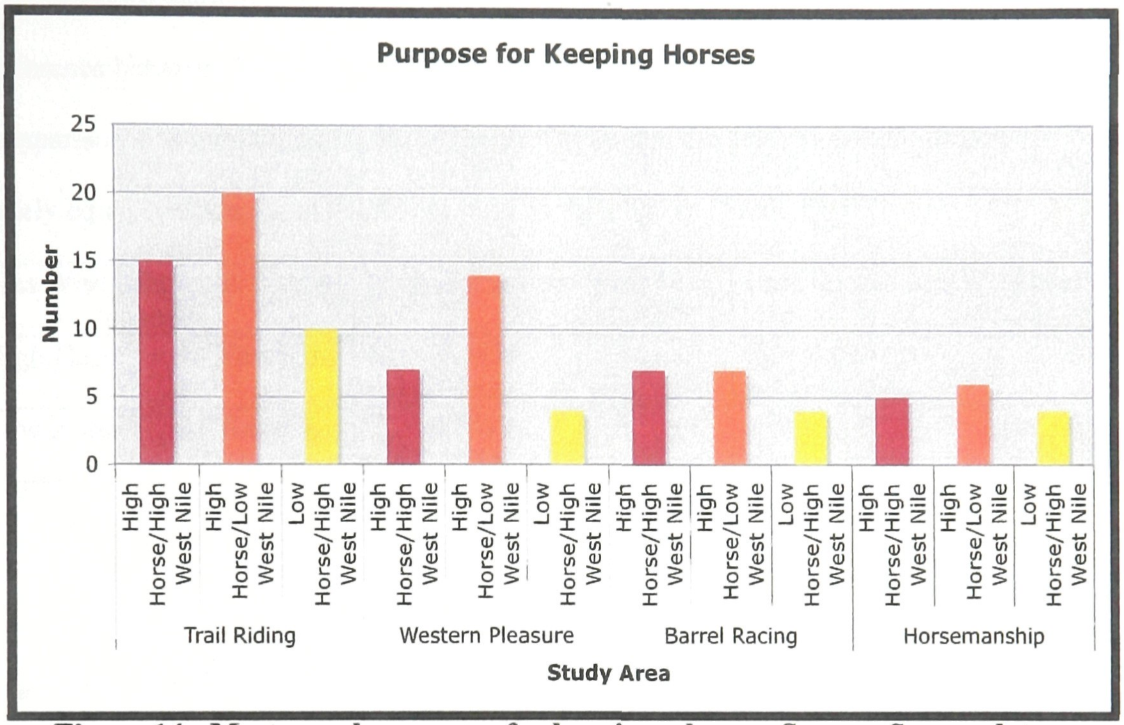


Figure 14: Most popular reasons for keeping a horse. Source: Survey data.

Quarter Horses-trailed this leisure pursuit (Figure 14).

Of those surveyed, 73 percent were concerned about West Nile virus and 27 percent did not think West Nile virus was a cause for concern. It is interesting to note that the High Horse/Low West Nile virus category appears to have slightly more concern about West Nile virus, although this category has the lowest rate of disease of the three groups (Figure 15).

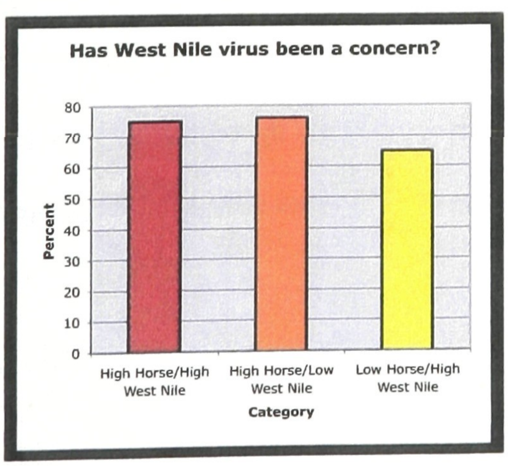


Figure 15: Concern about West Nile virus in equine populations. Source: Survey data.

The two-sample difference of proportions test showed that there was no significant difference between the three categories in level of concern. Because the p value for each comparison was greater than 0.05, table four shows that the study populations have nearly equal concern about West Nile virus in their horses (Table 4).

Has West Nile virus been a concern?	High Horse/Low West Nile	Low Horse/High West Nile
High Horse/High West Nile	$Z_p = -0.0854$ $p = 0.9362$	$Z_p = 0.6644$ $p = 0.5092$
Low Horse/High West Nile	$Z_p = 0.8573$ $p = 0.3954$	

Table 4: Question #8 "Has West Nile virus been a concern?"

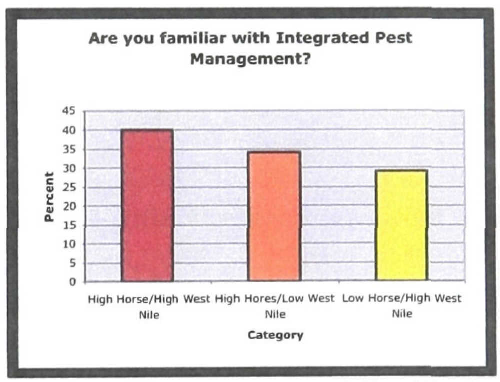


Figure 16: Horse owners' and barn managers' familiarity with IPM practices. Source: Survey data

Survey question 9 asked if a respondent is knowledgeable about mitigation of mosquito habitat by asking "Are you familiar with Integrated Pest Management?" Only 32 percent were familiar with IPM, and only 28 percent were practicing IPM techniques (Figure 16). Although these numbers are low, on the positive side they show that the majority of those who know of IPM are using techniques to control mosquito habitat.

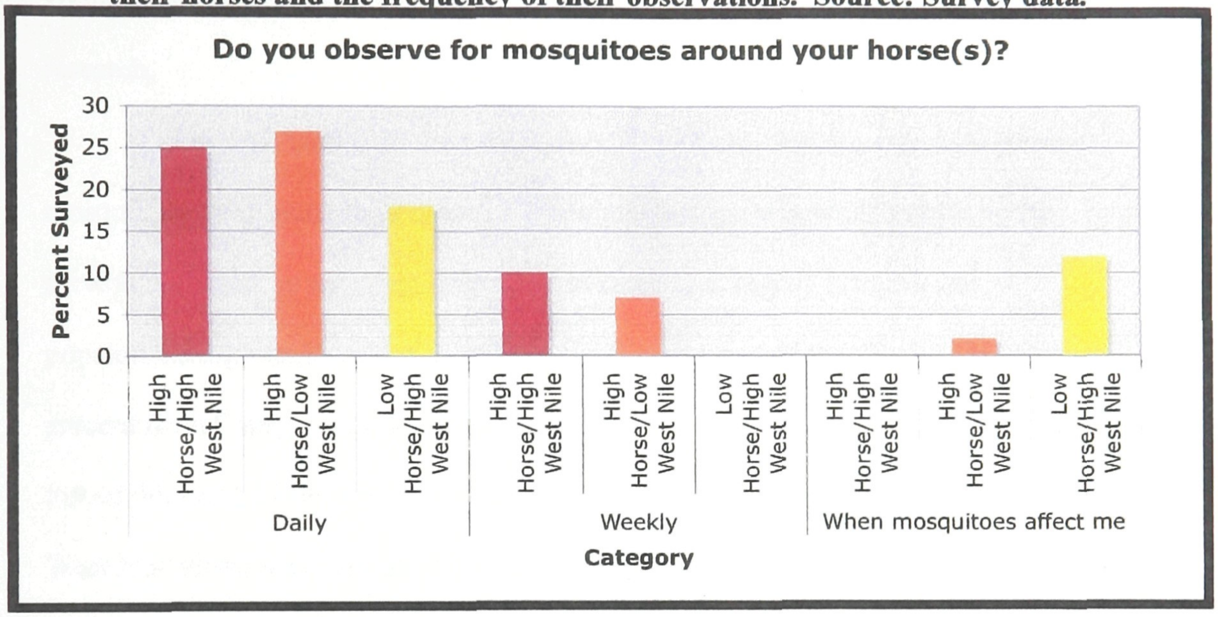
Do you practice IPM?	High Horse/Low West Nile	Low Horse/High West Nile
High Horse/High West Nile	$Z_p = -0.1582$ $p = 0.8808$	$Z_p = -0.3242$ $p = 0.749$
Low Horse/High West Nile	$Z_p = -0.2215$ $p = 0.8258$	

Table 5: Question #10 "Do you practice Integrated Pest Management techniques?"

As table 5 shows, there was no statistical difference in the percentage of respondents practicing IPM, thus suggesting that knowledge and use of IPM is not one of the factors contributing to different levels of disease among categories. However, while only 28 percent of respondents were using IPM techniques, 53 percent of those surveyed thought that using IPM techniques would help to prevent West Nile virus in horses. This higher percentage shows that increased education in IPM techniques may increase the use of IPM.

At this point in the survey, many respondents would ask me the definition of Integrated Pest Management. I would explain that IPM incorporated observance for mosquitoes, reducing mosquito habitat, administration of pesticides and vaccines, and education about insect control. After hearing the definition of IPM, respondents would then answer question 11, "Do you feel that using IPM would help you to protect your horses?" This leaves 72 percent of respondents not using all the tools at their disposal to prevent West Nile virus or other mosquito-borne disease. Public education of IPM techniques may help to reduce mosquito-borne disease and reduce dependence on insecticides and repellents. Most people were aware of common mosquito habitat, which included containers for holding water, water bodies, and wetlands. The suggestion is that public education of mosquito habitat has been successful. The majority of respondents surveyed, 60 percent, observed for mosquitoes around their horses, although only three participants, 3 percent, recorded their observations.

Figure 17: Horse owners/barn managers' observance of mosquitoes around their horses and the frequency of their observations. Source: Survey data.



While many respondents claimed to observe for mosquitoes around their horses, many do not observe on a regular basis (Figure 17). Half of those respondents that answered question 14 followed up on the second part of the question which was "If so, how often?" The second part of question 14 was open-ended and many of the respondents chose not to answer that part of the question. The results from this question show that most people do observe for mosquitoes, although few are doing so with any regularity throughout the mosquito season. As mosquito populations can fluctuate for many different reasons, checking for mosquitoes regularly may be beneficial in determining if animals should be vaccinated or IPM techniques applied in an area. It seems that less than 30 percent of respondents are observing for mosquitoes to prevent West Nile virus or other mosquito-borne disease. As with question 8 (Has West Nile virus been a concern?), it appears that more respondents from the counties with high horse populations and low incidents of West Nile observe for mosquitoes daily. Is West Nile virus in equine populations lower in these counties because of their owner's vigilance, or due to another factor? This question would be a good area for continuing research.

Fewer than half of all the participants, 47 percent, used insecticide to prevent mosquitoes from biting their horses. When the question was broken down by the surveys collected by category, 60 percent of those in Category I (high horse populations/high incidence of West Nile virus) used insecticides (Figure 18). Forty-six percent from Category II (high horse populations/ low incidence of West Nile virus) used insecticides and 41 percent from Category III (low horse populations/high incidence of West Nile virus) used insecticides to control mosquito bites on their animals. It would be interesting to follow up by asking respondents if they increased their use of pesticides after West Nile virus became an issue in 2002. It would also be interesting to know if pesticide use has decreased now that West Nile virus is discussed with less frequency in the news media.

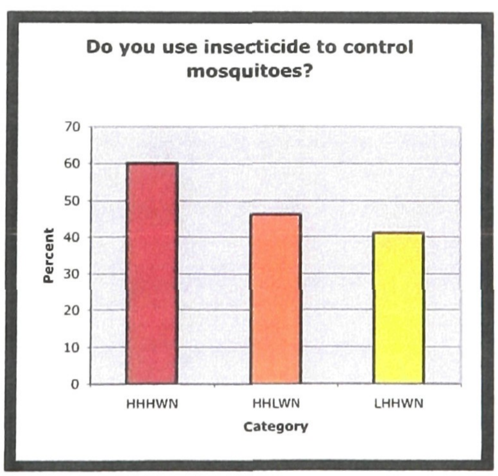


Figure 18: Use of insecticide to control mosquitoes. Source: Survey data.

Do you use insecticide to control mosquitoes?	High Horse/Low West Nile	Low Horse/High West Nile
High Horse/High West Nile	$Z_p = 1.0279$ $p = 0.3087$	$Z_p = 1.1529$ $p = 0.2502$
Low Horse/High West Nile	$Z_p = 0.3489$ $p = 0.7338$	

Table 6: Question #21 "Do you use insecticide to control mosquitoes?"

Despite the variation in percentage responding "yes," Table six shows that there is not a statistically significant difference in pesticide usage between the three study areas. This statistic indicates that each study area uses approximately similar amounts of caution when applying pesticides to and around their animals. However, this statistic does not explain the differences in incidents of West Nile virus between study areas.

Of those surveyed, 20 percent responded that they applied insecticide in their barn area. Of those, 19 percent specified the frequency of insecticide application. The responses were broken down by study area. Figure 19 shows the usage of pesticide in the barn area by category and by frequency of application. Respondents from the category with low horse populations and high incidence of West Nile virus appear to apply pesticide in the barn with the greatest frequency. Frequency of pesticide application depends on the pesticide used, and the products vary widely in duration of efficacy. Insecticides can be effective for 40 minutes to 14 days, depending on the ingredients. Most insecticides used around horses were created to reduce fly populations although most are also effective against mosquitoes. The majority (80%) of horse owners/barn managers are not controlling mosquitoes in their barns.

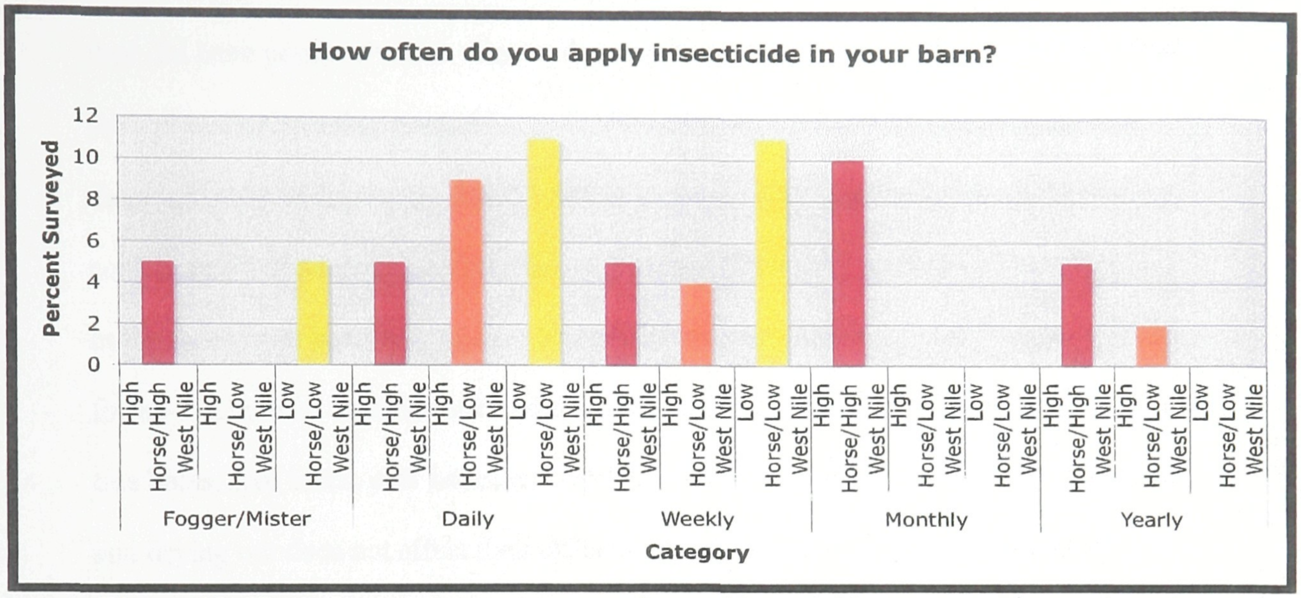


Figure 19: Horse owners/barn managers' use of insecticide to control mosquitoes in their barns.

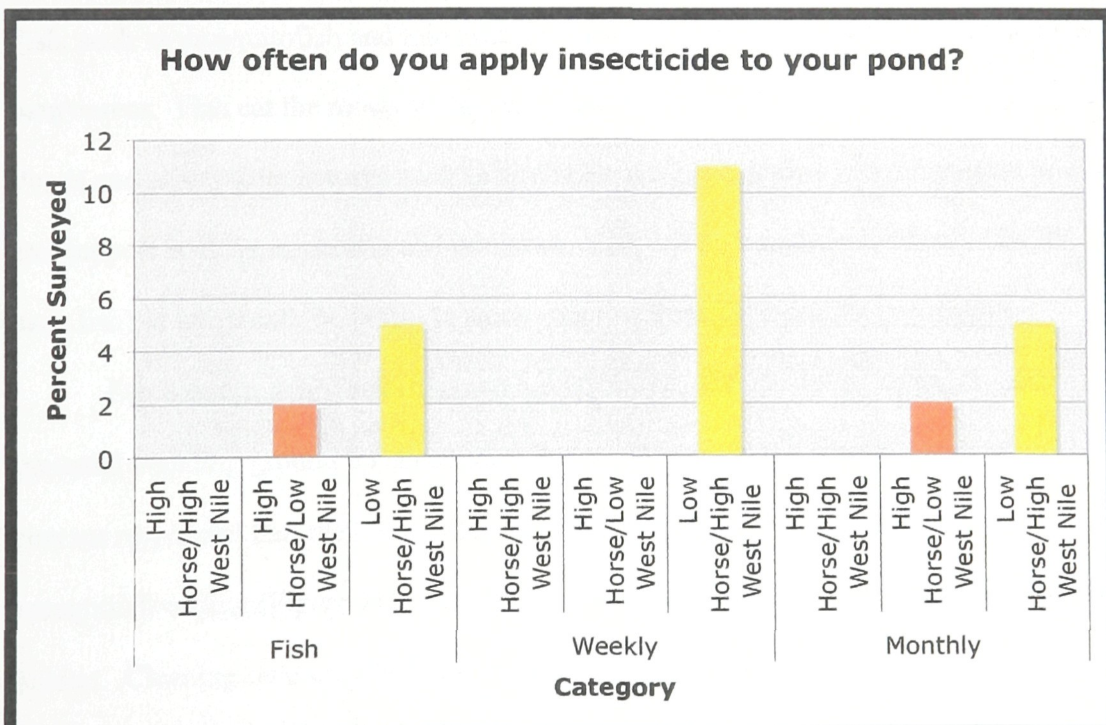


Figure 20: Horse owners/barn managers' use of insecticide to control mosquitoes in their ponds. Source: Survey data.

When asked if they applied insecticide to their ponds, 7 percent answered that they did have ponds in which they used mosquito prevention methods (Figure 20). Ponds are a potential breeding ground for mosquitoes, but mosquito larvae can be controlled though the use of "mosquito dunks" and by keeping fish in the pond. Mosquito dunks contain bacillus thuringiensis israeliensis, bacteria that works as a larvicide to prevent mosquitoes from becoming adults. Mosquito dunks are slow release and can be effective for up to a month. Dunks can be used anywhere that catches and holds water, including tree holes, bird baths, sink holes, and ditches. Dunks can be broken into smaller pieces, and drying out does not affect their efficacy. However, only a small percentage of respondents answered that they made use of mosquito dunks. Dunks are inexpensive ($2.00 each), yet effective way to control many different mosquito breeding grounds. Fish, such as mosquitofish and minnows can be used to control mosquito populations in many areas. Fish eat the mosquito larvae, which then reduces the mosquito population. Ponds and other water sources such as birdbaths, drainage ditches and ornamental ponds can support both mosquitofish and minnows. Fish can be bought individually ($0.20/ each fish) or by pound ($6.00/lb) to stock water sources for mosquito prevention.

Stock tanks, open tanks that can hold from 70 -100 gallons of water, are also a potential breeding ground for mosquito breeding (Figure 20). Of those surveyed, 16 percent responded that they have stock tanks and regularly manage them to prevent mosquito breeding (Figure 21). Like ponds, mosquito dunks and fish can limit mosquito habitat. Cleaning on a weekly basis will also prevent stock tanks from becoming mosquito breeding grounds. This question was also broken down by category and frequency. The majority of respondents to this question treated their stock tanks regularly and with frequency. Eighty four percent of respondents did not answer this question, so it is unclear how many respondents actually have stock tanks.

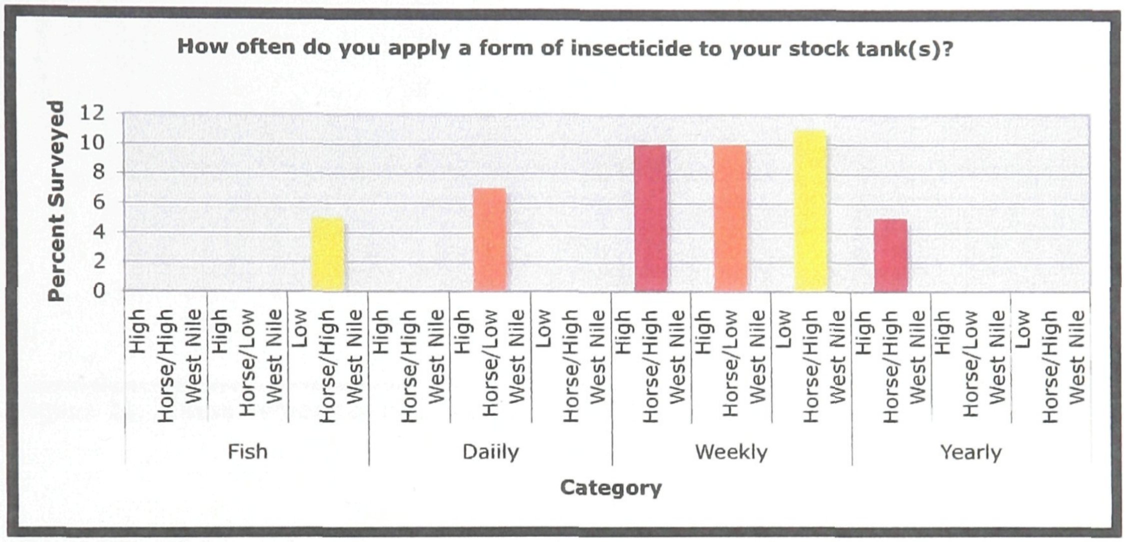


Figure 21: Horse owners/barn managers' use of insecticide to control mosquitoes in their stock tanks. Source: Survey data.

A key method of preventing mosquito-borne diseases is application of mosquito repellent. Of those surveyed, thirty-six percent applied insect repellent to their horse(s) (Figure 22). This question was also broken down by category and frequency of application. There are many different sprays available for repelling mosquito bites on horses and a variation in the length of time that the sprays remain effective. Some popular chemicals that repel mosquitoes and other insects include (in order of length of efficacy) pyrethrin, permethrin, oil of citronella, and Avon's Skin So Soft. Mosquito repellents that contain pyrethrin claim 5 -14 days efficacy. Repellents that contain permethrin claim 4 – 6 hours of efficacy. Products that contain oil of citronella can repel mosquitoes for 1 – 2 hours. Avon Skin So Soft offers only 40 minutes of protection. Length of efficacy can be reduced due to factors such as temperature (as temperature increases, products become less effective), wind, and if the animal gets wet or sweats.

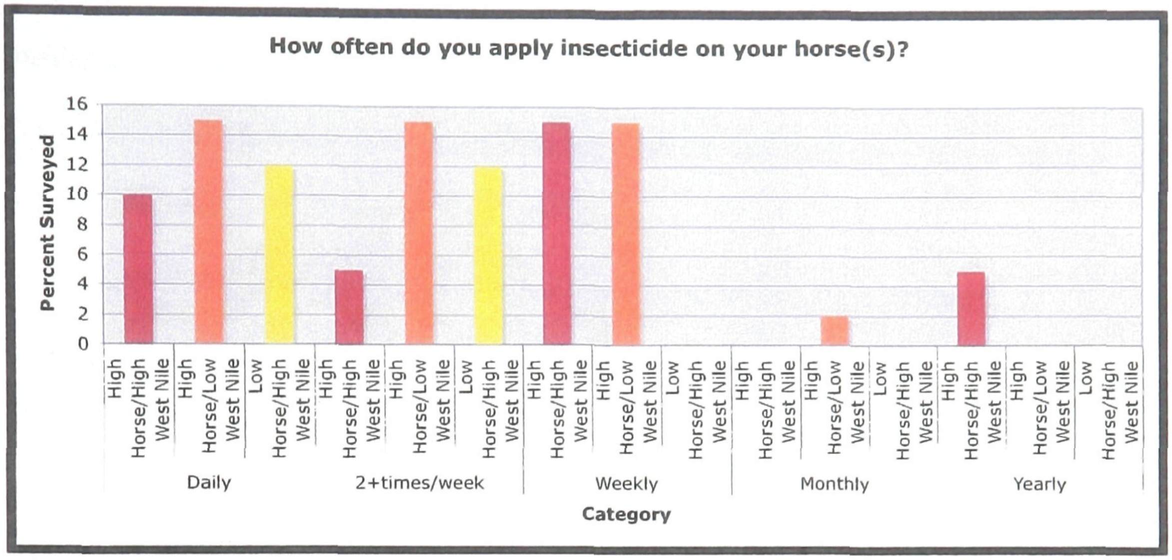


Figure 22: Horse owners/barn managers' use of insecticide to control mosquitoes on their horses.

The most popular mosquito suppression device, other than insecticide, was citronella products (33 percent), followed by bats (15 percent), and then bug zappers (13 percent). Products containing at least five percent citronella oil are eighty-eight percent effective as mosquito repellents with up to two hours of exposure (Fraden, 1998). However, Fraden (1998) found no statistically significant difference between burning citronella candles or unscented, plain candles. Likewise, the use of bats and birds as predators for mosquito populations is questionable. It has not been proven that these predators consume enough mosquitoes to be effective. Bug "zappers" are also ineffective at reducing mosquito populations through electrocution. In fact, it has been suggested that these devices kill more beneficial insects than female mosquitoes (Fraden, 1998).

West Nile vaccines for horses have been available since 2001. Of those surveyed, 66 percent use one of the two vaccines available. Responses to the question 'Do you vaccinate your horse(s) for West Nile virus?" were broken down by category to look for statistical differences (Table 7). The statistics show that there is not a significant difference in vaccination practices between areas with high horse populations and high incidence of West Nile virus and areas with high horse populations and low incidence of West Nile virus. However, there is a significant difference between areas of low horse populations and high incidence of West Nile virus and each of the two areas with high horse populations. This response shows that fewer horse owners from low horse populations and high incidence of West Nile virus are vaccinating their animals as those from areas with high horse populations.

Do you vaccinate your horse with a West Nile virus vaccine?	High Horse/Low West Nile	Low Horse/High West Nile
High Horse/High West Nile	$Z_p = 0.8823$ $p = 0.3788$	$Z_p = 7.51$ $p = 0$
Low Horse/High West Nile	$Z_p = 2.04$ $p = 0.0414$	

Table 7: Question #24 "Do you vaccinate your horse with a West Nile virus vaccine?"

Most of those surveyed who vaccinate their animals do so with a yearly booster after the initial vaccination process (Figure 23). However, two respondents from category II answered that they gave the vaccine biannually during mosquito season to manage against West Nile virus most effectively.

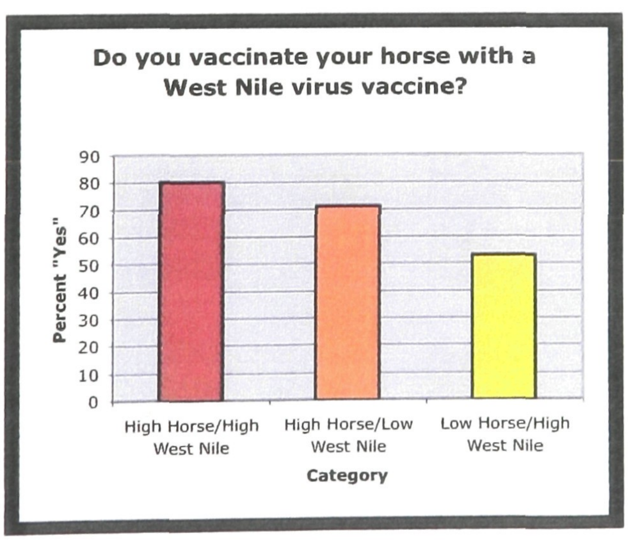


Figure 23: Horse owners/barn managers' use of vaccinations to prevent West Nile virus in their horses. Source: Survey data.

According to the manufacturers, West Nile-Innovator (Fort Dodge Animal Health) and RecombiTEK (Merial) work differently, but are ninety-five percent effective if a horse is vaccinated correctly and before the onslaught of mosquito season. However, only thirty-six percent of those surveyed felt that vaccinations provided full protection for their animals against West Nile virus (Figure 24).

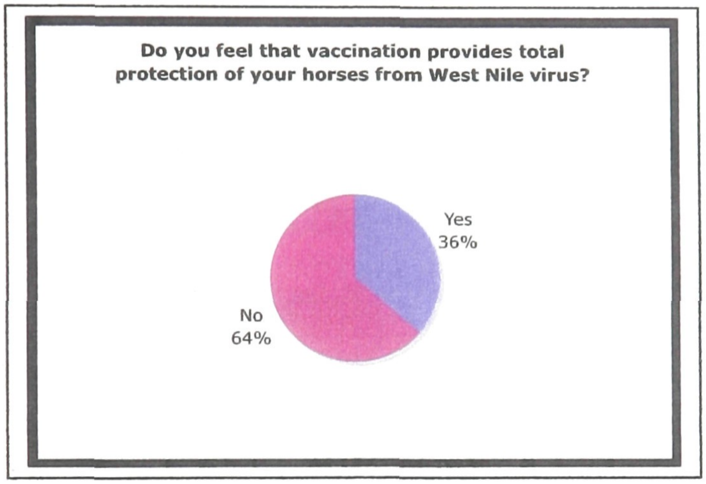


Figure 24: Horse owners/barn mangers' perception of the efficacy of a West Nile virus vaccine. Source: Survey data.

When asked if any of their horses had developed West Nile virus, 4.5 percent of respondents indicated they had an animal with the disease since 1999 (Figure 25).

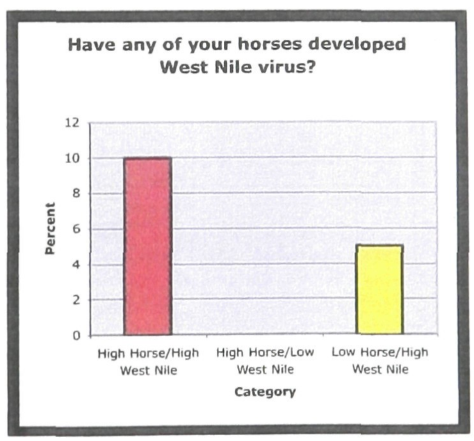


Figure 25: Respondents whose animals have had West Nile virus. Source: Survey data. Source: Survey data.

Have any of your horses developed West Nile virus?	High Horse/Low West Nile	Low Horse/High West Nile
High Horse/High West Nile	$Z_p = -0.6512$ $p = 0.5156$	$Z_p = 0.038$ $p = 0.976$
Low Horse/High West Nile	$Z_p = -1.445$ $p = 0.1498$	

Table 8: Question #28 "Have any of your horses developed West Nile virus?"

Respondents from high horse populations and high incidence of West Nile virus had the highest number of horses with the disease; however, no statistical difference in the percent of people responding "yes" was found between the categories (Table 8).

When asked if any neighbors' animals had developed West Nile virus, those in areas with high incidence of West Nile virus had the perception that there were cases of West Nile virus amongst their neighbors horses. There was a statistical difference in areas with high incidence of West Nile virus and areas with low West Nile virus (Table 9).

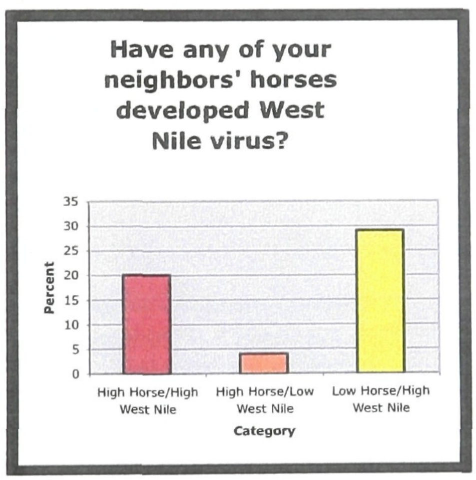


Figure 26: Respondents whose neighbors' horses have had West Nile virus. Source: Survey data.

Respondents from these counties have a greater perception that there are cases of West Nile virus in their neighbors' horses than respondents from the low West Nile virus category (Figure 26). Additionally, respondents from areas with low horse populations and high incidence of West Nile virus also have a greater perception that their neighbors' horses have had incidents of West Nile virus. These results make sense within the context of the question and the structure of the C use these two categories are located in regions of high incidence of W equine populations and hence, responses may reflect reality.

Have any of your neighbor's horses developed West Nile virus?	High Horse/Low West Nile	Low Horse/High West Nile
High Horse/High West Nile	$Z_p = 2.055$ $p = 0.0404$	$Z_p = -0.6387$ $p = 0.5286$
Low Horse/High West Nile	$Z_p = -2.736$ $p = 0.0064$	

Table 9: Question #29 "Have any of your neighbor's horses developed West Nile virus?"

The final question in the survey posed the question "Are you concerned that your neighbors' mosquito management practices may contribute to mosquito-related disease in your horses?" Only twenty-eight percent of those surveyed felt that their neighbors' management practices would influence their animals (Figure 27). There was no significant difference between the three category's level of concern over their neighbors'

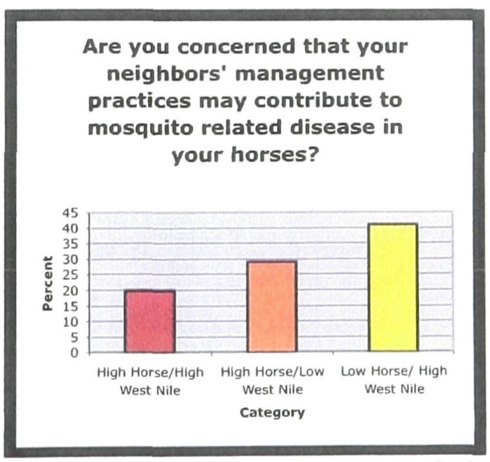


Figure 27: Respondents whose have concern over their neighbors' equine management practices in limiting mosquito-borne disease. Source: Survey data.

equine management practices (Table 10). Concern that their neighbors' management practices would contribute to mosquito-borne disease in the respondent's horses was not greater or lesser across the study area.

Are you concerned that your neighbors mosquito management practices may contribute to mosquito related disease in your horses?	High Horse Low West Nile	Low Horse High West Nile
High Horse High West Nile	$Z_p = 0.4849$ $p = 0.6312$	$Z_p = -1.39$ $p = 0.1646$
Low Horse High West Nile	$Z_p = 0.8882$ $p = 0.3788$	X

Table 10: Question #30 "Are you concerned that your neighbors mosquito management practices may contribute to mosquito related disease in your horses?"

Overall, the survey results showed that there is not a significant difference between categories when it comes to equine management practices and the use of Integrated Pest Management techniques to reduce mosquito habitat around horses. However, it does appear that respondents in areas with larger horse populations tend to vaccinate their horses with a West Nile virus vaccine more than those in areas with low horse populations. Reliability in survey design and administration may not provide similar results if this research were to be repeated. Conducting more surveys for each category may show different results because of a larger and possibly more accurate sample population. Additionally, the majority of surveys were collected by going to horse shows and other equine events. This factor may bias the survey results because many people that are involved in horse show activities require a healthy animal to participate, as opposed to people that keep horses as backyard pets. Finally, surveys may not provide accurate data because respondents may answer questions as following the accepted norms instead of recording their actual equine management practices.

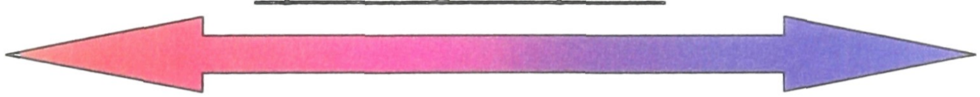
CHAPTER VII

DISCUSSION

I. Differences in Equine Management Practices

Through the course of the research, I found a wide spectrum of management practices used in preventing West Nile virus in horses. This research demonstrates that, on one side of the spectrum, some horse owners and managers are making an effort to prevent mosquito-borne disease. These horse people actively educate themselves about potential mosquito-borne diseases, vaccinate their animals regularly against West Nile virus, and reduce mosquito habitat around their animals. On the other side of the spectrum are horse owners and managers who seem to have an apathetic response to combating mosquito-borne disease. These horse people are not actively making any overtures to prevent mosquito-borne disease in their animals.

Equine Management Spectrum



Apathetic in West Nile virus prevention **Active in West Nile virus prevention**

Figure 28

Of course, the majority of horse owners and barn mangers fall in the middle of the spectrum (Figure 28). These horse people make decisions to vaccinate their animals depending on such factors as finances, infected animals in their vicinity, veterinarian recommendations, and media attention to the disease.

However, besides a more frequent use of a West Nile virus vaccine in areas with high horse populations, little difference exists between the three categories' equine management practices. There is a roughly equal level of concern over West Nile virus between the three categories and a similar degree of concern over neighbors' mosquito management practices. This research suggests that management practices do not differ significantly between areas of high and low incidence of West Nile virus, as originally hypothesized. Differences in equine management practices can be ruled out as a cause of West Nile virus outbreaks.

Throughout the research process, I was able to interview several people who have direct experience in the Kentucky horse world. First, I interviewed two horse breeders on either side of the equine management spectrum to examine some of the differences between their management practices. I also interviewed two Kentucky veterinarians, one with a local practice and the other with a position in the state government, to find their views on common equine management practices.

The first equine veterinarian I interviewed actively practiced mosquito-borne disease prevention in the animals with which he worked. This approach represents the side of the spectrum that actively practices West Nile virus prevention. As this interview took place at the very beginning of my research, I did not yet have the survey to administer. This veterinarian is employed by a large thoroughbred breeding facility that has operations on three continents. Some of the stallions in the breeding operation were former Kentucky Derby winners and thoroughbred champions in the United States or abroad. Stud fees for the stallions range from $7,500 to $300,000 for the 2006 breeding year. Each animal has a private caretaker and the stallions live in barns that have vaulted ceilings and varnished hardwood interiors. The veterinarian explained that the stallions are vaccinated two to three times per year for West Nile virus. This practice is opposed to the more typical vaccination process, where an animal is given a yearly booster in the spring after the first round of the vaccination process given the previous year. The recommended course of action as outlined by the American Association of Equine Practitioners suggests giving the West Nile virus vaccination throughout the course of mosquito season, approximately every four months, as determined by warm weather conditions (AAEP, 2005). However, only two of the horse owners/managers who completed the survey vaccinate for West Nile virus more that once a season, although the mosquito season in Kentucky is generally longer than four months.

The breeding facility and grounds are maintained to prevent pooling or stagnant water and other possible mosquito habitat. In order to prevent local mosquito populations, mosquito dunks containing a bacteria that kills mosquito larvae are frequently utilized in the ponds and streams located on the grounds of the facility throughout mosquito season. During the course of this study, data revealed that only three of those surveyed used an insecticide in ponds or streams to mitigate mosquito populations close to their horses. Two respondents make use of fish that would consume water-borne insect eggs or larvae in their ponds or watering tanks. None of the animals at this breeding facility died due to West Nile virus or showed signs of having contracted West Nile virus testifying to the efficacy of these practices.

One other horse breeding facility was visited, an American Saddlebred breeding and horse showing operation. This facility represents the opposite side of the equine management spectrum, those apathetic to West Nile virus prevention. This interview was conducted after the survey was created, so I was able to include this facility in the survey data. The facility had over 300 horses, with most of the animals living exclusively on pasture throughout the year. The horses for sale at the Saddlebred facility range in price from $1,000 to $25,000. This facility did not check for mosquitoes around their horses or use insecticide to control mosquito populations anywhere on the facility grounds. Additionally, none of the horses has been vaccinated against West Nile virus. When this action was questioned during the interview, the owner replied that the cost of vaccination for the entire herd outweighed the cost of one animal lost due to West Nile infection. None of the horses at this facility had died or showed signs of having contracted West Nile virus.

Practicing veterinarians are in a unique position to observe the spectrum of equine management practices because they are frequently called to the location where the animal lives. I had the opportunity while gathering data to speak with Dr. Vice (DVM) from Fleming County Animal Hospital. Fleming County is located in one of my study categories and is a county with a high horse population and high incidence of West Nile virus. Dr. Vice offered some insight into equine management practices amongst horse people he saw while visiting his patients. Dr. Vice observed that the majority of people he sees do not vaccinate their horses with a West Nile virus vaccine. He told me that the majority of people he observes vaccinating their horses have experienced a problem with West Nile virus or know someone whose horse had West Nile virus. He went on to say that he saw many people at the beginning of the West Nile virus outbreak vaccinate their animals mainly due to media attention. Since 2002, the number of people who have Dr. Vice vaccinate their horse against West Nile virus has dropped. Dr. Vice had not seen any cases of West Nile virus in 2005, the year of our conversation. He said that he has not seen cases of Eastern Equine encephalitis or St. Louis encephalitis since the 1970's although he vaccinates for those diseases on a regular basis. Dr. Vice told me that he believes that the West Nile virus vaccines are an effective way to prevent the disease in horses. However, he also said that he finds it hard to convey the importance of a consistent equine vaccination program to horse owners in his region.

Another perspective on equine West Nile virus occurrences in Kentucky comes from the Assistant State Veterinarian Dr. Sue Billings. I asked Dr. Billings why she thought that incidence of West Nile virus has dropped since its peak in 2002. She believes that one of the reasons is increased mosquito control by individual counties. She went on to say that treatment and prevention of West Nile virus has improved since the disease was first introduced to the United States. She believes that another possible reason for declining deaths due to equine West Nile virus is that veterinarians and horse owners are better educated in recognizing the symptoms of West Nile virus and animals can be treated when they are discovered to be sick.

While talking with some of the respondents during the course of the survey, I was able to find out some of the reservations horse owners have about vaccinating their horses against West Nile virus. One of the first people to give their opinion on the West Nile vaccine was a man who would not vaccinate his horses because he believed that the West Nile vaccine caused abortion in pregnant mares. This gentleman stated that he had found this information while surfing the Internet. The information that this man had found was likely the result of a newspaper report originating in The Denver Post (Henderson, 2003). The report claimed the Fort Dodge West Nile Innovator vaccine caused abortion and deformed foals after vaccination of pregnant mares. However, this information was not due to a scientific study as none of the animals were tested for West Nile virus.

Spokesmen from Colorado State University, University of Wyoming, and the United States Department of Agriculture responded to the report and explained to the public that "none of the veterinary diagnostic laboratories in the United States are seeing this syndrome or associating it with west Nile virus" (University of Wyoming, 2003, p.1). The initial media reports had done damage as this information spread through common media channels with the result that some horse owners and barn managers interviewed for this study decided against West Nile virus vaccination. Foregoing vaccination due to misinformation belongs on the apathetic side of the equine management spectrum. The owners and barn managers who decided against vaccination should follow up on the report of abortion and deformation of foals to fully assess the situation. One other horse owner volunteered, while taking the survey, that she did not use the West Nile virus vaccination anymore because her horse "had a bad reaction" after vaccination. The respondent was not clear about the exact symptoms her horse experienced, just that her horse was "off." Although the horse recovered, the owner was hesitant to use a West Nile virus vaccination again in the future. This horse owner would fall in the middle of the equine management spectrum and could implement Integrated Pest Management as a way to protect her animal against exposure to mosquito-borne disease.

II. Future Diffusion

West Nile virus has spread rapidly throughout the United States since its introduction in 1999. This disease is likely to reach all areas of mosquito habitat in North, Central, and South America before the decade is out. West Nile virus cases in the Caribbean Basin during 2001 have been documented by the Center for Disease Control and Prevention (CDC, 2006). The disease was then detected in Mexico in the summer of

2002, northern Central America in 2003, and Colombia in 2004 (Komar and Clark, 2006). Studies on Eastern and Western Equine Encephalitis show that bird migration facilitates the virus's expansion into other regions. According to Rappole *et al.* (2000, p.320) this evidence reinforces the likelihood that migratory birds "play a major role in virus transport."

The spread of West Nile virus and other mosquito-borne diseases is difficult to predict due to the many factors involved in transmission. Dr. Paul Reiter (2005), a professor in the Insects and Infectious Disease Unit at the Institut Pasteur in Paris, France, comments that "transmission dynamics of (mosquito-borne) disease are complex; the interplay of climate, ecology, mosquito biology, mosquito behavior and many other factors defies simplistic analysis" (Reiter, 2005, p.1). In fact, the most devastating epidemic of malaria happened in the Soviet Union with many cases occurring close to the Artic Circle (Reiter, 2005, p.1). This outbreak suggests that temperature and climate are among the many factors that contribute to mosquito-borne disease but are not limiting factors.

Rappole *et al.* (2000) anticipated that due to mosquito control operations in New York during 1999, West Nile might not ever become established in the United States. While communities applied insecticide over mosquito and human habitat early in the spread of West Nile virus, many currently spray only for nuisance mosquito bites and then only after a request has been made. According to Chris Regan, of the Mosquito Control Department of the Kentucky Department of Agriculture, spraying in Kentucky counties happens only after a judge-executive, mayor, or public health official requests spraying. Public areas such as parks, ball fields, and neighborhoods that are experiencing more than a nuisance number of mosquito bites are sprayed according to a schedule. Mosquito habitats outside of large human settlements are commonly left alone due to budget restrictions. An employee from the Jessamine County Health Department says that the spraying in her county has lessened in the last two years, although the Kentucky Department of Agriculture does a good job with controlling mosquito populations in public areas such as parks and fair grounds. Allen County, like Jessamine County, is located in an area with high horse populations and low incidence of West Nile virus. Donny Fitzpatrick of the Allen County Health Department said that he has not seen an increase in mosquito spraying in his county since West Nile virus was first introduced to the area. Some counties do not use the Kentucky Department of Agriculture to control mosquitoes. For example, according to county officials, Warren County has seen as much as a 50% increase in mosquito spraying by the county officials since the introduction of West Nile virus in 2001. This varying approach to mosquito control is significant because it implies that mosquito-borne disease could continue to spread unchecked, especially in areas outside of human habitation, such as wild bird and mosquito habitat. The consequence is that mosquito-borne disease will be restricted in urban locations only after the mosquito population has become an aggravation to the human populace. Any new mosquito-borne disease introduced to the United States will be free to move and spread throughout the country as easily as West Nile was able to do after its introduction in 1999. Even in its worst year in terms of human infections, West Nile virus only affected 0.0034 percent of the population in the United States (CDC, 2006). The number of humans infected continues to drop, and media attention has decreased. This lack of attention suggests to the public that West Nile virus may go the way of malaria and yellow fever, two mosquito-borne diseases no longer seen as a significant threat to human heath in this country. However, diseases mutate and become resistant to commonly used drugs just as insects mutate and become resistant to commonly used pesticides. The chance of another mosquito-borne disease penetrating the borders of the United States is no longer a probability, as we have seen with the spread of West Nile virus through the Americas.

CHAPTER VIII

CONCLUSION

Mosquitoes and mosquito-borne disease have caused health complications in human and animal populations since the mosquito evolved over 170 million years ago. Mosquitoes are quite talented in their ability to reproduce rapidly and adapt to changes in environment. Fossil records of mosquitoes show that the malaria virus has been present for over 30 million years (Chang, 2002). According to the American Mosquito Control Association (AMCA, 2006), over 1 million people die due to mosquito-borne diseases every year. Limiting mosquito-borne disease is an important preventive strategy that could protect the health of both horses and humans. Horses are practical subjects to study the distribution and impacts of mosquito-borne disease because of their geographic mobility and their connection to the local environment. As this research has demonstrated, in Kentucky there is a connection between high horse populations and greater use of West Nile virus vaccines. There is also a connection between low horse populations and a lack of use of a West Nile virus vaccine. However, other than vaccination practices, this study demonstrates that equine management practices are not significantly different between areas that experience high incidence and low incidence of West Nile virus and areas of high and low horse populations. This research also demonstrates that few horse owners and barn mangers take actions to limit mosquito habitat around their animals. This oversight could prove to be a problem in the future if another mosquito-borne disease with no available vaccination is introduced into the United States. Vaccination lowers the chance that a horse will develop West Nile virus, but researchers from Colorado State University state "it is important for equine owners to employ other strategies for prevention of the disease including mosquito mitigation" (APHIS, 2003, p.1). Active equine management programs that include proper use of West Nile vaccinations and limiting mosquito habitat by making full use of county insecticide programs are essential in the future prevention of mosquito-borne disease.

The study of mosquito-borne disease encompasses many factors, such as temperature and rainfall, potential mosquito habitat, non-mosquito carriers of the disease, the use of pesticides and more. One of the problems encountered at the beginning of this study was the lack of point data for locations of cases of West Nile virus in Kentucky. This information is protected by the Kentucky Department of Agriculture, and case locations are not released to the public at a scale more specific than the county. One of the reasons for this is to maintain privacy, similar to how privacy laws protect human patients. Protecting this information is important to maintain the privacy of Kentucky's horse community just as it is important to maintain this privacy in humans. For this reason, the state Department of Agriculture or the Center of Disease Control and Prevention may be able to take the research process further than this study was able to accomplish. Access to point data would have been useful in employing Geographic Information Systems (GIS) to research connections between the disease and climate, land use, geology, and elevation. The county incidence of equine West Nile virus data used in this study was too broad to effectively study the correlations between disease and topographic issues. If point data for equine West Nile virus in Kentucky were put into a GIS database with land use and climate data then this would allow for overlays to buffer areas such as wetlands. Mosquitoes typically do not travel more than one mile from where they were born; thus looking at areas such as wetlands and using the buffer of one mile while examining the overlay point data of West Nile virus incidence could show areas susceptible to mosquito-borne disease. Similarly, GIS could be used to look at monthly climate data to create models predicting mosquito prevalence. Additional research could also examine simple regression in incidence of West Nile virus and average income levels or education levels for each county to determine if these issues are significant.

APPENDIX I

EQUINE WEST NILE VIRUS INCIDENTS
KENTUCKY, 2002
KENTUCKY DEPARTMENT OF AGRICULTURE

2002-Jun	FAYETTE	1
2002-Jul	ANDERSON	1
2002-Jul	BARREN	2
2002-Jul	FAYETTE	2
2002-Jul	GREENUP	1
2002-Jul	HART	1
2002-Jul	MARION	1
2002-Jul	NELSON	1
2002-Jul	WHITLEY	1
2002-Aug	ADAIR	10
2002-Aug	BARREN	18
2002-Aug	BOURBON	2
2002-Aug	BOYLE	6
2002-Aug	BRECKINRIDGE	1
2002-Aug	BUTLER	1
2002-Aug	CALLOWAY	5
2002-Aug	CARLISLE	4
2002-Aug	CASEY	1
2002-Aug	CUMBERLAND	1
2002-Aug	DAVIESS	1
2002-Aug	FAYETTE	12
2002-Aug	FLEMING	11
2002-Aug	FRANKLIN	1
2002-Aug	GARRARD	1
2002-Aug	GRAVES	2
2002-Aug	GREEN	4
2002-Aug	HENRY	6
2002-Aug	HOPKINS	1
2002-Aug	JESSAMINE	1
2002-Aug	LARUE	1
2002-Aug	LAUREL	1
2002-Aug	LEWIS	2
2002-Aug	LINCOLN	1
2002-Aug	LOGAN	6
2002-Aug	MADISON	1
2002-Aug	MARION	13
2002-Aug	MARSHALL	1
2002-Aug	MASON	2
2002-Aug	MCCRACKEN	2
2002-Aug	MERCER	2
2002-Aug	METCALFE	4

2002-Aug	MONROE	1
2002-Aug	NELSON	21
2002-Aug	OLDHAM	3
2002-Aug	PULASKI	2
2002-Aug	RUSSELL	4
2002-Aug	SCOTT	1
2002-Aug	SHELBY	3
2002-Aug	TODD	9
2002-Aug	TRIGG	1
2002-Aug	UNION	7
2002-Aug	WARREN	1
2002-Aug	WASHINGTON	2
2002-Aug	WEBSTER	1
2002-Aug	WOODFORD	2
2002-Sep	ADAIR	4
2002-Sep	ALLEN	1
2002-Sep	ANDERSON	1
2002-Sep	BALLARD	1
2002-Sep	BARREN	14
2002-Sep	BATH	1
2002-Sep	BOONE	4
2002-Sep	BOURBON	8
2002-Sep	BOYLE	3
2002-Sep	BUTLER	1
2002-Sep	CALLOWAY	5
2002-Sep	CAMPBELL	2
2002-Sep	CARLISLE	5
2002-Sep	CARTER	1
2002-Sep	CHRISTIAN	2
2002-Sep	CLARK	1
2002-Sep	CRITTENDEN	3
2002-Sep	DAVIESS	6
2002-Sep	ESTILL	3
2002-Sep	FAYETTE	23
2002-Sep	FLEMING	10
2002-Sep	GARRARD	2
2002-Sep	GRAVES	5
2002-Sep	GRAYSON	5
2002-Sep	GREEN	2
2002-Sep	HARDIN	3
2002-Sep	HARRISON	1
2002-Sep	HART	3
2002-Sep	HENDERSON	6
2002-Sep	HENRY	6
2002-Sep	HICKMAN	1
2002-Sep	HOPKINS	1
2002-Sep	JEFFERSON	10

2002-Sep	JESSAMINE	2
2002-Sep	LARUE	3
2002-Sep	LINCOLN	9
2002-Sep	LOGAN	1
2002-Sep	MADISON	2
2002-Sep	MARION	5
2002-Sep	MASON	1
2002-Sep	McCRACKEN	3
2002-Sep	MCLEAN	1
2002-Sep	MERCER	4
2002-Sep	METCALFE	2
2002-Sep	MONROE	2
2002-Sep	MONTGOMERY	4
2002-Sep	MORGAN	2
2002-Sep	MUHLENBERG	1
2002-Sep	NELSON	10
2002-Sep	NICHOLAS	1
2002-Sep	OLDHAM	4
2002-Sep	PENDLETON	2
2002-Sep	PULASKI	8
2002-Sep	ROCKCASTLE	1
2002-Sep	RUSSELL	9
2002-Sep	SCOTT	8
2002-Sep	SHELBY	14
2002-Sep	SPENCER	5
2002-Sep	TAYLOR	3
2002-Sep	TODD	5
2002-Sep	TRIMBLE	1
2002-Sep	UNION	1
2002-Sep	WARREN	6
2002-Sep	WASHINGTON	4
2002-Sep	WEBSTER	2
2002-Sep	WOODFORD	7
2002-Oct	BARREN	1
2002-Oct	BOURBON	1
2002-Oct	BRECKINRIDGE	2
2002-Oct	BULLITT	1
2002-Oct	CALLOWAY	1
2002-Oct	CAMPBELL	1
2002-Oct	CRITTENDEN	1
2002-Oct	CUMBERLAND	1
2002-Oct	DAVIESS	1
2002-Oct	ESTILL	1
2002-Oct	GRAVES	2
2002-Oct	GREEN	1
2002-Oct	HARDIN	1
2002-Oct	HARRISON	1

2002-Oct	HENDERSON	2
2002-Oct	LINCOLN	1
2002-Oct	MCLEAN	1
2002-Oct	MERCER	2
2002-Oct	NELSON	2
2002-Oct	OHIO	2
2002-Oct	OLDHAM	1
2002-Oct	PULASKI	2
2002-Oct	SHELBY	1
2002-Oct	TAYLOR	1
2002-Oct	WARREN	1
2002-Oct	WOODFORD	4
2002-Nov	BALLARD	1
2002-Nov	BUTLER	1
2002-Nov	GRAYSON	1
2002-Nov	MARSHALL	1
2002-Nov	NELSON	1
2002-Nov	WARREN	1

APPENDIX II

KENTUCKY INVENTORY OF EQUINES BY COUNTY
2002 CENSUS OF AGRICULTURE

Table 15. Horses and Ponies - Inventory and Number Sold: 2002 and 1997

[For meaning of abbreviations and symbols, see introductory text]

Geographic area		Inventory		Sold	
		Farms	Number	Farms	Number
STATE TOTAL					
Kentucky	2002	20 054	149 465	[illegible]	[illegible]
	1997	[illegible]	[illegible]	[illegible]	[illegible]
COUNTIES, 2002					
Adair		304	2 004	78	341
Allen		287	1 864	57	153
Anderson		170	1 031	42	128
Ballard		88	530	32	47
Barren		429	2 443	54	334
Bath		152	1 035	50	167
Bell		17	73	3	[illegible]
Boone		246	1 732	76	231
Bourbon		334	[illegible]	[illegible]	[illegible]
Boyd		119	220	43	65
Boyle		226	3 472	[illegible]	103
Bracken		127	903	26	[illegible]
Breathitt		42	175	14	[illegible]
Breckinridge		237	1 143	15	129
Bullitt		182	1 148	[illegible]	[illegible]
Butler		111	624	[illegible]	[illegible]
Caldwell		122	647	31	142
Calloway		171	1 112	17	[illegible]
Campbell		173	1 002	45	47
Carlisle		61	315	[illegible]	56
Carroll		82	430	[illegible]	20
Carter		263	1 507	[illegible]	247
Casey		224	1 298	45	[illegible]
Christian		274	1 575	[illegible]	[illegible]
Clark		254	1 445	[illegible]	[illegible]
Clay		65	305	[illegible]	23
Clinton		133	776	25	101
Crittenden		169	1 122	42	[illegible]
Cumberland		85	475	16	[illegible]
Daviess		192	1 017	[illegible]	161
Edmonson		140	424	15	98
Elliott		111	545	[illegible]	75
Estill		114	593	33	41
Fayette		426	10 676	292	2 123
Fleming		241	1 540	52	1 771
Floyd		[illegible]	71	[illegible]	[illegible]
Franklin		148	851	[illegible]	202
Fulton		34	245	[illegible]	35
Gallatin		57	208	[illegible]	25
Garrard		212	1 395	42	102
Grant		220	1 047	[illegible]	[illegible]
Graves		265	1 450	58	[illegible]
Grayson		373	2 126	48	[illegible]
Green		165	876	17	112
Greenup		192	1 119	18	159
Hancock		40	315	5	23
Hardin		437	2 728	105	411
Harlan		[illegible]	19	1	[illegible]
Harrison		248	1 634	[illegible]	137
Hart		[illegible]	1 045	[illegible]	193
Henderson		104	613	[illegible]	34
Henry		170	1 305	18	171
Hickman		34	184	6	8
Hopkins		125	914	[illegible]	37
Jackson		145	642	[illegible]	[illegible]
Jefferson		192	1 613	64	[illegible]
Jessamine		[illegible]	[illegible]	[illegible]	[illegible]
Johnson		18	207	4	5
Kenton		125	781	[illegible]	64
Knott		[illegible]	[illegible]	[illegible]	[illegible]
Knox		81	427	[illegible]	[illegible]
Larue		193	1 057	[illegible]	[illegible]
Laurel		215	1 332	[illegible]	[illegible]
Lawrence		76	774	[illegible]	[illegible]
Lee		35	208	[illegible]	[illegible]
Leslie		7	37	[illegible]	[illegible]
Letcher		6	17	2	[illegible]
Lewis		102	576	21	74
Lincoln		205	1 425	45	107
Livingston		107	752	24	[illegible]
Logan		178	972	35	132
Lyon		57	404	14	34
McCracken		116	802	36	[illegible]
McCreary		40	145	3	5
McLean		37	209	[illegible]	[illegible]
Madison		320	1 998	[illegible]	181
Magoffin		47	326	[illegible]	[illegible]
Marion		211	1 128	11	[illegible]
Marshall		214	1 167	42	[illegible]
Mason		176	1 142	25	109
Meade		246	1 412	62	183
Menifee		110	535	22	54
Mercer		213	2 532	[illegible]	[illegible]
Metcalfe		122	1 111	[illegible]	151
Monroe		144	[illegible]	15	31
Montgomery		145	932	44	131
Morgan		235	1 267	54	[illegible]
Muhlenberg		150	727	33	[illegible]
Nelson		226	2 305	101	[illegible]
Nicholas		145	1 157	15	[illegible]

--continued

APPENDIX III

Consent Form

Dear Sir or Madam,

My name is Sara Dalton and I am a graduate student at Western Kentucky University working on my Master of Science degree in Geoscience. I am collecting data to determine which equine management practices contribute to reducing the spread of mosquito-borne disease in horses. I am focusing on interviews with horse owners and those professionals that manage horses.

I appreciate your participation in this survey and I would like you to know that any information you provide will be kept confidential. This means that the survey documents will be kept in a locked cabinet in a locked office. The individual survey responses will never be shared with anyone else. Only summary results of the survey will be used in my thesis. The surveys will be destroyed after completion of the thesis process.

You are being asked to participate in this thesis project conducted through Western Kentucky University. The University requires that you give your signed consent to participate in this project. Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time for any reason with no penalty.

Thank you for your assistance. I am grateful for your help.

Sara Elizabeth Dalton

Graduate Student
Western Kentucky University
270-991-2190
sara.dalton@wku.edu

____
(Your signature)

____
(Date)

APPENDIX IV

Integrated Pest Management Survey

Sara Elizabeth Ali, Department of Geography and Geology, Western Kentucky University

Background	
1. Are you a horse owner?	Yes No
2. Do you derive income from horses?	Yes No
3. Do you manage horses for someone else? If so, please answer the rest of the survey for the horses you manage.	Yes No
4. In which Kentucky county do the horses you own or manage live?	
5. How many horses do you own or manage?	
6. What breed(s) are your horses?	
7. What is your purpose for keeping horses? (Circle those that apply) Western Pleasure Cutting Roping Barrel Racing Racing Hunter/Jumper Trail Riding Driving Equitation Horsemanship Reining Rodeo Dressage Cross Country Endurance Other____________________	
Integrated Pest Management	
8. Has West Nile Virus been a concern?	Yes No
9. Are you familiar with Integrated Pest Management?	Yes No
10. Do you practice Integrated Pest Management techniques?	Yes No
11. Do you feel that using Integrated Pest Management would help to prevent West Nile Virus disease in your horses?	Yes No
Prevention	
12. Please list all areas you believe to be mosquito-breeding habitat.	
13. How many days does it take for a mosquito to breed after hatching?	#________

Surveillance		
14. Do you observe for adult mosquitoes around your If yes, how often?	Yes	No
15. What specific areas do you check?		
16. Do you observe at the same time every day?	Yes	No
17. What time of day?		
18. Do you use any surveillance devices other than observation, such as attractant-baited traps? If so, what devices and where are they used?	Yes	No
19. Do you observe for mosquitoes …		
In the barn?	Yes	No
In your dry-lot corals?	Yes	No
In your turnout fields?	Yes	No
In your horse watering habitat, (ponds, water buckets, watering tanks, ect.)?	Yes	No
20. Do you record surveillance observations for adult mosquitoes?	Yes	No
Suppression of Mosquitoes with Pesticides		
21. Do you use insecticides to control mosquitoes?	Yes	No
22. Where, which, and how often do you apply insecticide for the prevention of mosquitoes?		

Where	Frequency	Pesticide
Barn		
Corals		
Turn out		
Ponds		
H2O buckets		
H2O tanks		

Horses Other_______	
23. I am going to read you a list of suppression devices. Please indicate those which you use. Bug Zappers Carbon Dioxide Devices Bats Ultra Sonic Devices Mosquito dunks Citronella Plants Do you use any other suppression devices that I have not named? Other_________	
Vaccination	
24. Do you vaccinate your horse with a West Nile Virus vaccine?	Yes No
If you answered yes to the question above, which vaccination do you use? (Circle one) West Nile Innovator Other_________	
25. How often do you vaccinate against West Nile Virus? (Circle one) Yearly booster Biannually Other________	
26. Do you feel that vaccination provides total protection of your horses from West Nile Virus?	Yes No
27. Have you done a cost comparison of an IPM program vs. the cost of vaccination?	Yes No
28. Have any of your horses developed West Nile Virus?	Yes No
29. Have any of your neighbor's horses developed West Nile Virus?	Yes No
30. Are you concerned that your neighbors mosquito management practices may contribute to mosquito related disease in your horses?	Yes No

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